JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 33 December, 1940 No. 6

Insect Vectors in Relation to Quarantine, Eradication, and Control of Plant Viruses

L. D. CHRISTENSON, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

A symposium covering the general subject of insects in relation to plant diseases was held during the fiftieth annual meeting of the American Association of Economic Entomologists. Excellent papers were presented by Granovsky (1938), Kunkel (1938), Leach (1938), Poos (1938), and Stevens (1938). Another review of this fascinating field of research is not the intent of the present paper, which deals instead with insect vectors of plant viruses in relation to certain phases of plant quarantine.

One result of the intense research activity characteristic of modern times is the common knowledge that viruses cause serious diseases of plants in many parts of the world, and that insects serve to spread many of these diseases. In a recent handbook Holmes (1939) discusses more than 100 species and strains of phytopathogenic viruses "affecting seed plants."* Insects are known to be concerned in the transmission of approximately one-half of the viruses treated. In the different virus groups as proposed by Holmes (1939) insect vectors have been discovered in number and percentage of cases as follows: Yellows group (Chlorogenaceae) 7, or 58.3 per cent; mosaic group (Marmoraceae) 35, or 47.9 per cent; ringspot group (Annulaceae), no vectors determined; fiji-disease group (Gallaceae) 1, or 25 per cent; spindle-tuber group (Acrogenaceae) 3, or 100 per cent; leaf-curl group (Rugaceae) 3, or 100 per cent; leaf-roll group (Coriaceae) 3, or 100 per cent; dwarf-disease group (Nanaceae) 3, or 37.5 per cent; savoy-disease group (Savoiaceae) 3, or 100 per cent; and spotted-wilt group (Lethaceae) 2, or 100 per cent.

As vectors of phytopathogenic viruses insects may be the only means of natural spread afforded, or they may supplement other methods. In either case they are an undeniable part of the virus disease complex and cause the problems often presented by these complexes to become the joint concern of the sciences of plant pathology and entomology. The result is that efforts to control plant disorders caused by viruses must take into account, to a degree dependent on the facts of each particular case, control of insects as well. Moreover, efforts to limit the spread of these diseases must take into account the organisms responsible for spread. When control measures for insects concerned in virus transmission are undertaken, they often must have a higher degree of effectiveness than is ordinarily required, since the percentage reduction in population which would be satisfactory in other insect-control work may permit the survival of a sufficient number of insects to cause virus disease outbreaks or insure continuance of existing damaging infections. The failure of normally efficient control measures to kill all individual insects of a vector species may likewise permit a sufficient number of viruliferous insects to survive to introduce a virus into previously uninfected areas.

The relationship of insect vectors to eradication and control problems can be illustrated best by first citing a hypothetical case of a fruit-tree virus which has been introduced and established by bud-

* Holmes omits discussion of numerous reported viruses because their affinities are considered uncertain. Relatively few vectors are reported for these. Doubtful records were disregarded in computations of percentages of viruses transmitted by insects.

ding, but in which insect transmission and other modes of natural spread are not, or have not, become involved.* In the absense of a natural mode of transmission, control of the supposed virus would be comparatively simple, consisting in the main of registration of disease-free trees suitable for budding and regulation of nursery stock.

When insects are involved in the natural spread of a fruit-tree virus the general aspects of the problem are very different. A means of tree-to-tree and orchard-to-orchard dispersal is at hand. The practice of diseased-tree roguing is changed from a desirable to a necessary one. Constant orchard inspection, often for a long period of years, becomes necessary. After budwood sources are brought under control, new infections, unless promptly removed, have a compounding effect on the number of subsequent infections.

The nature, degree, and pattern of spread are unpredictable and depend on factors that influence flight habits and population densities of insects. There is at hand a ready means whereby the virus can perpetuate itself in widely scattered alternate susceptible or carrier hosts. After the last-known diseased tree has been removed in an infected area, there may be viruliferous vector individuals still at large, capable of infecting additional trees. It may be necessary to work on methods of controlling vector species, particularly if natural spread occurs to a degree more than offsetting the effect of diseased-tree removal. Studies of insects concerned in transmission may be required so that population changes and consequent acceleration or retardation in the rate of disease spread may be predicted. Regulatory measures, especially those referring to nurseries, gain added significance. In general, the effect of insect transmission may be such as to jeopardize the successful control of plant virus disease, or prevent, or postpone attainment of, complete eradication.

It also becomes important to consider the movement of plant host material in relation to vectors as well as in relation to the virus diseases around which the mechanism of regulations operates. In the case of phony peach and of peach mosaic diseases, inspection of nurseries and environs and sources of budwood and environs involves only the demonstration of the viruses, since the vectors of these diseases are unknown. However, any quarantine designed to prevent spread of peach yellows would necessarily include consideration of the plum leafhopper (*Macropsis trimaculata* Fitch), known to transmit the virus of peach yellows.

Increasing knowledge of plant viruses and the insects responsible for transmission of them has added further evidence of the wisdom of the present policy, under the so-called Insect Pest Act of 1905, of strict exclusion of all phytophagous insects. The following partial list of virus vectors and plant viruses not yet occurring in the continental United States that are transmitted by them may be of interest in this connection: *Cicadulina mbila* (Naude), known to transmit maize-streak virus, typical strain, maize-streak virus, cane-streak strain, and maize-streak virus, mottle strain, in Africa; *C. zeae* China, another vector of maize-streak virus, typical strain, and maize-streak virus, mottle strain; *C. storeyi* China, a vector of maize-streak virus, typical and mottle strains; *Peregrinus maidis* (Ashm.), the vector of maize-mosaic virus; *Nephotettix apicalis* var. *cincticeps* Uhler and *Deltocephalus dorsalis* Motsch., transmitters of rice-dwarf disease in Japan; *Aphis leguminosae* Theob., the vector of peanut-rosette virus in Africa, Madagascar, and Java; *Perkinsiella saccharicida* Kirk., the vector of fiji-disease virus of sugarcane in Queensland; *P. vastatrix* Breddin, a vector of fiji-disease virus of sugarcane in the Philippine Islands; *Eriophyes ribis* Nalepa, a mite vector of black-currant reversion-disease virus in the British Isles; *Bemisia gossypiperda* M. & L., the vector of tobacco leaf-curl virus in Africa, India, and Sumatra, and cotton leaf-curl virus in Sudan and Nigeria; *B. gossypiperda* var. *mosaicivectura* M. & G., a vector of cassava-mosaic virus in the Belgian Congo and Tanganyika; *B. nigeriensis* Corb., a vector of cassava-mosaic virus in South Nigeria; *Piesma quadrata* Fieb., the vector of beet-kräuselkrankheit virus in Germany and

* Such a case is considered to be represented in nature by psorosis, a disease of citrus presumably introduced prior to 1896, which is thought to be of virus origin. Fawcett (Calif. Citrograph 24 (7): 242–62, illus.) reports that there is little or no tree-to-tree spread of this disease in California.

Poland; and *Lygus pratensis* L., responsible for transmission of rape-savoy virus in Germany. Some of the insect species listed already occur in the United States, but this is not sufficient reason to except them since, if infective, individual insects may introduce the viruses they transmit. Many of the viruses listed attack agricultural plants of importance to the economic welfare of the United States.

Biological reasons for exclusion of insect vectors of plant viruses are quickly apparent. First, interception of known insect vectors of plant viruses that depend solely on specific insects for spread may prevent establishment of the viruses, provided no indigenous species are capable of serving in a vector capacity; second, exclusion of known vectors of plant viruses that have become established, or may become established, throuh other modes of transmission will have the effect of simplifying control of these viruses by preventing or postponing complicating influences of an insect method of spread; third, interception of known vectors which do not occur in the United States, but which transmit plant viruses that do, will prevent unwelcome additions to present methods of spread; fourth, interception of known vectors may prevent introduction and possible establishment of plant viruses through the medium of viruliferous individuals, which often remain infective for long periods of time, even while feeding on immune plants; and, fifth, exclusion of known vectors may prevent establishment of insects that have potentialities as plant pests, aside from ability to transmit the virus. Undoubtedly there are other justifications which could have been cited.

Because of its general bearing on the subject of insect vectors in relation to plant quarantine and as an example of the type of study desirable in this connection it may be of interest to discuss peach mosaic-vector research being conducted by the Bureau of Entomology and Plant Quarantine in cooperation with the Bureau of Plant Industry, of the United States Department of Agriculture, and with various State agencies.

Peach mosaic is a highly infectious virus disease of peach occurring in widely scattered areas of Texas, Oklahoma, Colorado, Utah, Arizona, New Mexico, and California. The natural method of spread is not known, but Hutchins *et al.* (1937) report that spread occurs readily among bearing and nonbearing trees under natural conditions and that the disease is not transported in irrigation water. Moreover, no inoculations through soil, cultivation, mechanical contact, pruning, or pollen, have been noted or obtained. All information, including that obtained by mosaic inspectors working under control and eradication projects, lends support to the probability that insects are concerned in natural transmission.

As a background for peach mosaic vector research it seemed desirable to explore the field of vector possibilities by conducting an insect survey of peach orchards throughout mosaic-infected areas. As a *modus operandi* for survey, a mobile laboratory, carrying equipment necessary to make it an entirely independent unit, was constructed and placed in operation. This survey unit has thus far accumulated approximately 23,000 records of insects occurring on peach, on related orchard cover plants, and in the soil of peach orchards, at all seasons of the year, over a 3-year period. Identification of much of this material* has permitted the choice of mosaic-vector suspect species, and has allowed the placing of proper test emphasis on these.

Approximately 1,200 exploratory tests, involving more than 40 species of insects and a mite, have been completed as of the present date, in field plots located at San Bernardino, Calif.,† and Brownwood, Tex.‡ Readings on most of these tests will not be possible until the spring of 1940. All of 204 tests completed late in the summer of 1938 showed no mosaic symptoms at the end of a year.

If vector research should result in the discovery of an insect mode of transmission for peach mosaic another method of suppressing this disease would be available. Suppression of population densities of a vector or vectors of peach mosaic, or regulation based on a knowledge of the habits of vectors, may prove necessary to the complete success of peach mosaic erad-

* Grateful acknowledgement is here made of the services rendered by the specialists of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in furnishing prompt identifications of large numbers of the insects collected in the course of the survey.

† In cooperation with L. C. Cochran, California Citrus Experiment Station, Riverside, Calif.

‡ In cooperation with L. M. Hutchins, Bureau of Plant Industry, U. S. Department of Agriculture, Brownwood, Tex.

ication and control, or at least facilitate attainment of the desired goal. Moreover, knowledge of a vector will provide an additional research tool whereby the relationships of various stone-fruit viruses to one another and to other viruses may be more thoroughly investigated. In the event that a vector or vectors are discovered, it is anticipated that further investigations will relate to the problems having a direct bearing on control and eradication activities.—3-16-40.

LITERATURE CITED

Granovsky, A. A. 1938. Insects in relation to diseases of truck crops. Jour. Econ. Ent. **31**(1): 11–9.
Holmes, F. O. 1939. Handbook of phytopathogenic viruses. Minneapolis, Minn.
Hutchins, L. M., E. W. Bodine, and H. H. Thornberry. 1937. Peach mosaic, its identification and control. U. S. Dept. Agr. Cir. **427**.
Kunkel, L. O. 1938. Insects in relation to diseases of fruit trees and small fruits. Jour. Econ. Ent. **31**(1): 20–2.
Leach, J. G. 1938. Insects in relation to diseases of shade and forest trees. Jour. Econ. Ent. **31**(1): 23–4.
Poos, F. W. 1938. Insects in relation to diseases of cereal and forage crops. Jour. Econ. Ent. **31**(1): 24–38.
Stevens, N. E. 1938. Problems involved in control of plant diseases and insects. Jour. Econ. Ent. **31**(1): 39–44.

The Cotton Leaf Worm in the Western Hemisphere

LOUIS PYENSON, *State Institute of Agriculture, Farmingdale, New York*

The initial spring infestations of the cotton leaf worm, *Alabama argillacea* (Hbn.) are generally considered to originate from moths migrating from southern regions perhaps thousands of miles away

FIG. 1.—Approximate dates of primary infestations of the cotton leaf worm, 1936–1937. A—present continuously; X—known to be present.

(Walcott 1929). There is no evidence that this insect can undergo a diapause in any of its stages and thus survive unfavorable conditions in any area. Very little is known about the insect throughout South America where it is one of the major pests of cotton, and where infestations in the United States are thought to originate. A knowledge of such movements may throw some light on the origin of the pest.

This paper deals mainly with observations on this insect made by the writer in Pernambuco, Brazil, in 1936 and 1937; and with other data kindly sent in by entomologists in South America in reply to a questionnaire. Tree cotton, both wild and cultivated, is very abundant in the interior of South America and is the chief host plant of the cotton leaf worm. Harland (1930) states that the cotton leaf worm can also breed on *Thespesia populnea*, a tree abundant in the tropics of the new world.

THE COTTON LEAF WORM IN PERNAMBUCO:—The cotton leaf worm appears annually in Pernambuco in destructive numbers at the beginning of the rainy season (Pyenson 1938 a and b). The initial infestations appear in the western part of the state a few weeks after the first rains fall and cotton foliage appears (Fig. 1). Cotton grown under irrigation near the coast of Pernambuco in the dry season

(August to February) is free from infestation. The infestations appear to spread eastward and northward as the rainy season advances. Harland (1930) reports that he was informed by Dr. O. Lamartine that in the state of Rio Grande do Norte the attack begins in the south and works towards the north. This state is just north of Pernambuco and Parahyba.

Near the coast in 1936 larvae were present from the latter part of March until early August. Five broods were observed during this time. The insect takes somewhat less than one month to undergo a complete life cycle. All attempts to find a stage in which the insect may undergo a diapause in the dry season failed. Usually only the first and second larval broods in any one area are present in numbers and cause appreciable damage. Early in May, 1937, hundreds of moths were seen flying around the lights at the top of a 10 story hotel near the ocean. These probably originated in a heavily infested cotton field some five miles inland. The later broods of larvae appear to be severely curtailed by predators and parasites (Pyenson 1938 a and b). Numerous tachinid flies were reared from larvae in cages. In a few cases it was observed that cotton plants placed inside cages were stripped of foliage, while no larvae and but slight damage could be observed on plants outside of the cages. The cage evidently protected the larvae from parasites and predators.

In Pernambuco and neighboring states initial outbreaks of the cotton leaf worm and their severity may be predicted by observations on outbreaks far in the interior on tree cotton. Since tree cotton is leafless during the dry season, outbreaks follow the advance of the rainy season.

THE COTTON LEAF WORM IN OTHER REGIONS.—Information on the cotton leaf worm in other sections of South America was kindly furnished by entomologists to whom a questionnaire was sent. The following are short summaries of the replies to the questionnaire (Fig. 1).

E. J. Hambleton, São Paulo, Brazil.—The pest appeared in north-western São Paulo about the end of November or early December (1936) on cotton $2\frac{1}{2}$ to 3 months old. The cotton was stripped in some areas. The insect was not observed in some fields until the very end of the season. There is no data to indicate that it overwinters here. Late maturing pupae did not overwinter in Minas Geraes. The pest evidently migrates in from the north as it is not present the year around.

Carlos A. Lizer y Trellis, Argentina.—The cotton leaf worm was first observed in northeastern Argentina in late December (1936). It was not observed in Northwestern Argentina until early February. There is a wide waste region between the eastern and the western part of the country. It is a pest throughout the growing season. No migrations were observed from the north.

L. D. Cleare, British Guiana.—The cotton leaf worm is known to occur. Cotton is not grown as a commercial product.

Albert S. Muller, Caracas, Venezuela.—The cotton worm appeared during the first week in December of 1937 in the extensive cotton planting around Lake Valencia, state of Aragua. The attack was not serious because plantings had been made early, and harvesting was already in progress in many fields. The dry period is from February to June; the rest of the year is considered rainy in that region.

Louis Maria Murillo, Colombia.—Cotton is native to Colombia. The cotton leaf worm has been a pest to Colombian farmers ever since cotton was cultivated. It has always been present in all the regions.

According to Harland (1936) severe attacks of the cotton leaf worm occur every year in Colombia. The cotton season comes to an end in February and March. The type of cotton grown in perennial.

Dr. J. E. Wille, Peru.—The cotton leaf worm is found from Pacasmayo northwards. In most cases the cotton worm appeared in the northern parts of Peru in April and May (1937). Cotton 3 to 4 months old was attacked. In June and July older and younger fields were attacked. The cotton leaf worm is found throughout the year. The cotton season differs in different regions—Puira and Chira, January to October; Pacasmayo, March to December. No inward migration from any direction was observed. West coast of Northern Peru may be the origin of northern migrations.

Wolcott (1929) from his observations in Peru, thought there was an annual inward migration of moths, since caterpillars disappear during the winter months.

S. C. Bruner, Cuba.—"So far as has been observed the cotton worm seems to be present in Cuba at all times of the year."

L. C. Fife, Puerto Rico.—"This cotton pest has been present continuously in Puerto Rico during the past two years (1936 and 1937). The island has two cotton sections with seasons at opposite periods of the year, so the pest is able to find suitable food supply at any time. There is considerable tree cotton with green leaves during most of the year. The pest often occurs in outbreak numbers. There is no doubt that this insect overwinters in this area."

According to Ballou (1929) no record was ever obtained of the cotton leaf worm living over from one season to another in the Windward Islands. Caterpillars were found at work in fields as late as December and January. The cotton leaf worm invades these islands each year from South America.

The first appearance of the larvae in the southern United States in 1937 was in Southern Texas on May 27. The insect was not reported from Florida until July 6 (Loftin 1937).

Entomology Department (Mr. Francelot), Ithaca, N. Y.—The first moths were caught in light traps at Ithaca, N. Y., on May 26, 1937. A few were caught in early June, and some in July and August. Moths arrived in abundance during late September and early October.

DISCUSSION.—The data presented is somewhat meager to permit the drawing of definite conclusions on the origin of the cotton worm; it indicates that careful observations are necessary, throughout South America, before any can be drawn. Certain facts are evident from the data.

The cotton leaf worm is capable of flying great distances as indicated by its appearance at Ithaca, N. Y., in late May and early June.

These moths evidently came from tropical regions and probably originated in the same regions as the moths causing the initial Texas infestation. The evidence indicates that this insect perpetuates itself chiefly through its habit of migrating from place to place where food and favorable environment may be found. In some favorable environments where food is avialable the year around the insects breed continuously and these regions may be centers from which migrational flights take place. There is no evidence to indicate that migrations from any regions are directional. It is possible that prevailing winds affect the direction of migrations. In the regions of South America migrations appear to follow closely the advent of the rainy seasons.

The infestations in Argentina originate from moths migrating from Southern Brazil. It seems improbable that migrations into Argentina take place from Peru as the cotton leaf worm has never been reported in the cotton regions of southern Peru. The initial infestations in São Paulo probably originated from the more northern interior Brazilian States where the growing season or rainy periods start much earlier. Southern Brazil and northern Argentina may serve as sources of northeastern Brazilian infestations.

Infestations in Pernambuco appear to be sources of more northward progress of the insect. Colombia and Peru may be centers for northward and eastward migrations. The presence of vast areas of wild tree cotton throughout the interior of South America supplies ample food for these pests during the rainy seasons when foliage is available. The rainy seasons vary greatly in different regions of South America and therefore a continuous source of supply is always available to such migrating insects as the cotton leaf worm.

Mexico and Central America are troubled by this pest but no information on its occurrence was obtained. It may be significant that the periods of heaviest infestations in the northeastern parts of Brazil and Peru (April, May, and June) coincide with the periods of initial infestations in the southern parts of the United States.—5-10-40.

LITERATURE CITED

Ballou, H. A. 1929. The status of the cotton leaf worm, *Alabama argillacea*, in the West Indies. Int. Cong. Ent. 4, Tr. **2**: 94–6.

Harland, S. C. 1930. A note on *Alabama argillacea*. Trop. Agric. **7**(10): 281.

Harland, S. C. 1936. Some notes on cotton in Colombia. Trop. Agric. **13**(2): 31–4.

Loftin, U. C. Summary for 1937. Insect Pest Survey Bul. **17**(10): 615–6

Pyenson, L. 1938a. The problems of applied entomology in Pernambuco, Brazil. Part I. The ecological conditions influencing the activities and abundance of insects in Pernambuco. Rev. de Ent. 8(3–4): 237–54. 3 figs.

Pyenson, L. 1938b. Idem. Part II. A survey of some of the pests of the crops of Pernambuco. Rev de. Ent. 9(1–2): 16–31.

Wolcott, G. N. 1929. The mystery of *Alabama argillacea*. Am. Naturalist. 63(684): 82–87.

Species and Variety Differences in Resistance to Aphid Injury in Vetch[1,2]

H. R. ALBRECHT, *Alabama Agricultural Experiment Station, Auburn, Alabama*

Infestations of the pea aphid, *Illinoia pisi* Kalt., which have occurred frequently on the winter legume plots at Auburn, have brought to light striking varietal differences in the resistance of vetches to aphid injury. Recovery from such attacks resulted if the infestations occurred during the warm periods of midwinter or early spring; but when they occurred in late May, which was more common, they served to hasten the maturity of the crop. Observations indicated that these late infestations might have been responsible in a measure for reductions in seed yields. Low seed yields, along with the high cost of seed produced elsewhere, have been the principal obstacles to the progress of the winter legume program in Alabama.

EVALUATION OF VETCH SPECIES AND VARIETIES.—A severe aphid infestation in the winter legume breeding plots in January 1937 provided the first opportunity for a study of varietal differences in resistance to aphid injury among the vetches. The entire area was uniformly infested and differences in degree of injury were becoming apparent by January 15. Notes on the extent of injury and the severity of the infestation were taken at that time. In almost every case the resistant families were bordered by susceptible or highly susceptible lines and the discovery of some tip injury in every instance is proof that aphid visitations to resistant vetches must have been numerous.

Table 1.—Reaction of vetch species and varieties to pea aphis injury.

RESISTANT[1]	SUSCEPTIBLE[2]	HIGHLY SUSCEPTIBLE[3]
Vicia sativa:	*V. sativa:*	*V. sativa:*
16462	02830 (Alba vetch)	13430
29933	18134	18141
71116	18805	20570
Hairy vetch (*V. villosa*)	34949 (Willamette vetch)	31084
Smooth vetch (*V. villosa var.*)	Sel 8	32195
Woollypod vetch (*V. dasycarpa*)	Commercial Common A	Commercial Common B
Wild vetch (*V. angustifolia*)	Hungarian vetch (*V. pannonica*)	Bitter vetch (*V. ervillea*)
V. melanops	*V. monantha*	Purple vetch (*V. atropurpurea*)
V. hybrida		
V. grandiflora		

[1] Injury confined to stem tips. Recovery rapid.
[2] Stem tips killed and stems severely damaged. Recovery slow.
[3] Practically all tissue killed. Recovery very slow. Some mortality.

The aphids were not molested until January 20, when it was decided to spray the plants with nicotine sulfate so that certain highly susceptible lines could be saved. Notes were taken at intervals following spraying to determine the rate of recovery of each species and variety from aphid injury. These data were taken into consideration in the evaluation of the various vetches.

The injury to lines designated as resistant (Table 1) was confined entirely to the stem tips and had been overcome by February 5.

[1] Published with the approval of the Director of the Alabama Agriculture Experiment Station.
[2] Early publication of this paper has been secured by payment of the costs of printing.

The vetches designated as susceptible were severely attacked and injured by the aphids. All stem tips were killed and the stems themselves were either badly damaged or destroyed. These lines recovered more slowly, but no signs of injury were apparent on February 29. As far as could be determined, none of the plants was inured beyond recovery as a result of the aphid attack.

The vetches listed as highly susceptible still showed signs of injury on March 3. Recovery here was slow and the new growth was stunted since practically all the older foliage had been destroyed by the aphids. Some mortality resulted in these lines, but except in the case of purple vetch, *Vicia atropurpurea* Desf., which was completely destroyed, the losses were slight.

The infestations of 1938 and 1939 were not as severe as that of 1937, but the vetches showed the same relative susceptibility to aphid injury. The infestations of 1938 and 1939 did not occur until after mid-May when the plants had attained their maximum size. The strains considered resistant showed no injury as a result of aphid attack; those designated as susceptible or highly susceptible were injured in the main only at the stem tips; purple vetch was again completely killed. The susceptible vetches seemed to mature more rapidly than the resistant. It is interesting to note that in 1939, of 4 lines of *Vicia sativa* No. 34947 planted in the breeding plots, 1 was severely injured by aphids, 2 were slightly injured, and 1 was not harmed. Of 40 hairy vetches, *V. villosa* Roth, included in a progeny test, 10 were injured by aphids.

While the tests of 1937 provided more satisfactory data on the degree of damage to foliage among the vetches, they gave no indication of the relation of aphid injury to seed production because the plants were not in flower at that early date (January). In 1938 and 1939 it was noted that the aphids readily attacked the inflorescences and green pods of even the resistant vetches. Experiments with caged resistant and susceptible plants did no more than substantiate the field observations. Comparisons of seed production of plants caged with aphids and caged to protect them from the insects were not possible because the environment within the cages did not favor seed setting.

Summary.—Vetch species and varieties within a species grown at Auburn, Alabama, differed considerably in the reaction of their foliage to injury resulting from attack by the pea aphid. An evaluation of the vetches under observation is given.

Field observations and tests with caged plants showed that the inflorescenses and green pods of both the resistant and the susceptible vetches could be severely damaged by aphids. It is probable that this injury limited the seed production of the vetches studied.—9-20-40.

Tests with Benzene, Paradichlorobenzene and other Insecticides Against the Tobacco Flea Beetle, *Epitrix parvula* (F.), in Plant Beds[1]

NORMAN ALLEN and W. A. SHANDS,[2] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Serious damage to tobacco is caused frequently by the feeding of adults of the tobacco flea beetle (*Epitrix parvula* (F.)) on the leaves, stems, and roots of the plants. Complete destruction of tobacco in plant beds may be caused by such feeding when the plants are very small. In addition to the direct damage caused by the feeding of the flea beetles on the small plants in the plant bed, it has been shown by Levin (1940) that the tobacco plant bed is the most important breeding ground of this beetle during the early part of the season.

Since Angell *et al.* (1935), McLean *et al.*

[1] In cooperation with the Bureau of Plant Industry, U. S. Department of Agriculture; the South Carolina Experiment Station at Florence, S. C.; and the North Carolina Department of Agriculture at Oxford, N. C.

[2] Assisted in the field at Florence by L. A. Schifino, J. M. Webb, J. W. Humphreys, and D. B. Lieux; and at Oxford by T. F. Henderson. Grateful acknowledgment is also expressed for the assistance rendered at Florence in 1939 by J. R. Mattison, who was responsible for weighing and applying all treatments; and in 1938 at Oxford to T. E. Smith, who performed similar duties.

(1937), Clayton (1938), Lunn & Mattison (1938), Clayton *et al.* (1939), and others had reported the application of benzene and paradichlorobenzene as control measures for downy mildew, *Peronospora tabacina* Adam, in tobacco plant beds, preliminary studies were begun by the authors and their associates in 1938 to determine the toxicity of these chemicals to the tobacco flea beetle in plant beds that were being treated esperimentally for blue mold. Considerable interest was manifest in these studies by the tobacco growers and by workers in other phases of research relating to tobacco. The work was continued and extended during the plant-bed season of 1939 because the period for such studies was of short duration in 1938.

TESTS IN 1938.—Experiments at Oxford, N. C., in 1938, consisted in exposing beetles in plant beds covering 10 or 20 square yards that were being treated daily with benzene and paradichlorobenzene. Volatilization of benzene in the plant beds was affected through a wick system (Gumaer, 1938), while that of the paradichlorobenzene was obtained by strewing the finely pulverized crystals on boards suspended in the center of the bed. The vapors were held in the plant beds by heavy sheeting having a thread count of approximately 68 by 72 strands per square inch. Test cages consisted of gauze-covered spools or cylindrical cups with the open end coveres with gauze. Usually five cages were placed at random on the soil among the small plants in a bed section receiving each treatment. Ten beetles to a cage were exposed to the vapor treatments which were made from 5 P.M. or 10 P.M. to 8 A.M. on two consecutive nights. In the daytime the covers of the plant beds were removed to give the young plants the ventilation necessary for growth. In two series of tests the final records of beetle mortality were made 24 hours after the second night's exposure and in another series they were made immediately following the second night of exposure.

Table 1 shows the average percentages of mortality obtained in three series of tests from beetles subjected to treatments with benzene and paradichlorobenzene in plant beds. While the percentages of mortality from the same application rate varied materially for the three tests, the mortality observed among beeltes caged in a plant bed receiving no treatment strongly indicated that neither benzene nor paradichlorobenzene was toxic to the beetle under the conditions of the experiment.

Three kinds of tests with paradichlorobenzene were conducted on large plants during the latter part of the plant-bed season at Florence, S. C., but positive information was obtained in only one of these tests. In this particular test, examined 10 days after treatment, it was found that paradichlorobenzene applied in areas 18 inches wide and 23 inches long at the rate of 3 ounces per square yard was very toxic to the beetle when the plant bed was tightly sealed with a cover containing 64 by 64 threads per square inch.

Table 1.—Average percentages of dead adults of the tobacco flea beetle at stated intervals in tobacco plant beds treated daily with benzene or paradichlorobenzene, Oxford, N. C., April, 1938.

Treatment and Rate of Application	Test No. 1		Test No. 2		Test No. 3	
	Beetles		Beetles		Beetles	
	No.	Per Cent Dead at 72 hrs.	No.	Per Cent Dead at 48 hrs.	No.	Per Cent Dead at 72 hrs.
Untreated	—	—	—	—	120	37.5
Paradichlorobenzene (0.2 oz. per sq. yd.)	—	—	50	28.0	40	35.0
Benzene (30 cc. per sq. yd.)						
Bed No. 1*	30	43.3	40	15.0	50	20.0
Bed No. 4*	50	60.0	50	22.0	40	20.0
Bed No. 2†	40	55.0	50	6.0	40	35.0
Bed No. 3†	50	42.0	50	16.0	50	18.0

* Vaporized between 5 p.m. and 8 a.m.
† Vaporized between 10 p.m. and 8 a.m.

TESTS IN 1939.—The tests in 1939 were conducted in plant beds designed for joint use in toxicity studies relating to the tobacco flea beetle and blue mold. This arrangement was thought to be well suited for the experiments because it provided for replication of the treatments within and between the beds. Replications, for the most part, were in plant-bed compartments covering 6 square yards whether the beds were 2 or 3 yards wide. The arrangement of the plant beds and the relationship of the different treatments are illustrated in figure 1.

The bed covers that were used in the experiments with the tobacco flea beetle consisted of cloth having thread counts ranging from 16 by 20 to 68 by 72 strands per square inch. Daily applications of the

paradichlorobenzene were made, and in most instances the crystals were spread on boards around the edges of the bed compartments (Fig. 2) while the application of benzene was by means of several wick systems.

The treatments were applied late in the afternoon. The covers were immediately spread over the bed, fastened in place, and allowed to remain until about 8 A.M., the succeeding day, when most of them were removed.

FIRST SERIES.—Beetles for the first series of tests were collected on nearby farms, and 100 were placed in each of 28 compartments. After each compartment had been treated for 10 days, a thorough examination was made to recover living and dead beetles. Although it was difficult to count the flea beetles in beds before some of the plants were removed for transplanting, the data from these tests indicated that paradichlorobenzene applied daily at rates of $\frac{1}{4}$, $\frac{1}{2}$, 1, and 2 ounces per square yard was not toxic to and apparently had little, if any, repellent action on the beetle where ordinary plant-bed cover was used. Where covers having a range of from 38 by 38 to 64 by 64 threads per square inch were used, a few beetles were killed, some were stupefied, thus reducing the length of time that some of them could feed, and the material had some repellent action, owing probably to slower dissipa-

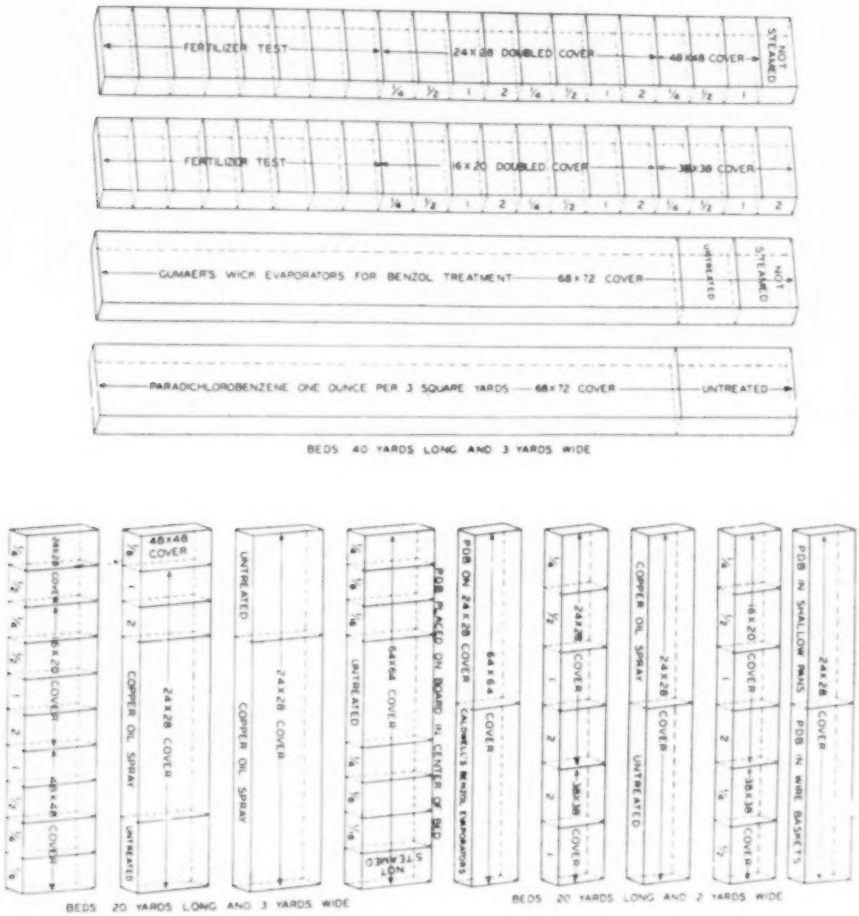

FERTILIZER TEST
24 x 28 DOUBLED COVER
48 x 48 COVER
NOT STEAMED
FERTILIZER TEST
16 x 20 DOUBLED COVER
GUMAER'S WICK EVAPORATORS FOR BENZOL TREATMENT
68 x 72 COVER
UNTREATED
PARADICHLOROBENZENE ONE OUNCE PER 3 SQUARE YARDS
BEDS 40 YARDS LONG AND 3 YARDS WIDE
48 x 48 COVER
COPPER OIL SPRAY
24 x 28 COVER
UNTREATED
POR PLACED ON BOARD IN CENTER OF BED
64 x 64 COVER
POR ON 24 x 28 COVER
CALDWELL'S BENZOL EVAPORATORS
COPPER OIL SPRAY
POR IN SHALLOW PANS
POR IN WIRE BASKETS
BEDS 20 YARDS LONG AND 3 YARDS WIDE
BEDS 20 YARDS LONG AND 2 YARDS WIDE

FIG. 1—The arrangement of tobacco plant beds and relationship of treatments used for their toxicity to blue mold, *Peronospora tabacina*, and the tobacco flea beetle, *Epitrix parvula*, at the Pee Dee Experiment Station in 1939. The daily application rates of paradichlorobenzene in ounces per square yard and the thread counts of plant-bed covers used are shown.

tion through the cover resulting in higher concentrations of the vapor. Similar results were observed in 100 square yards of bed having a cover containing 68 by 72 strands per square inch where the rate of application of paradichlorobenzene was 1 ounce per 3 square yards.

The results obtained from similar but less extensive tests with benzene indicated that this material was even less toxic to the beetle than paradichlorobenzene.

SECOND SERIES.—While the early tests indicated some toxicity, a need for more accurate tests with the heavier plant-bed covers was evident, and for this reason a second series of tests was run with small, loosely woven cloth bags into each of which 50 beetles with a green tobacco plant for food were placed. These bags were placed in different beds and in different areas of the same bed for a comparison of the toxicity of various rates of paradichlorobenzene when applied under plant bed covers containing 38 by 38, 48 by 48, 64 by 64, and 68 by 72 threads per square inch. The number of dead beetles was determined each morning for 3 consecutive days after treatment began.

The results of these tests are presented in table 2. Although the number of beetles killed was low, others were frequently observed to be inactive in the bags when they were removed from the bed. These stupefied beetles soon recovered when exposed to outside conditions. A similar but less extensive test showed that benzene had little, if any, toxicity for the beetle.

THIRD SERIES.—The first two series of tests were conducted primarily to determine the toxicity of these chemicals to the beetle. Aside from their toxicity, and probably of greater importance, is the possible protection from beetle injury afforded the plants by their application. The procedure used in the tests did not necessarily give a measure of the plant protection obtained because the insects were confined in small bed units or in cloth bags at specific points within the beds. A third series of experiments was therefore conducted on large plants in more open plant beds in a manner that made possible a more definite measure of insect toxicity and plant protection.

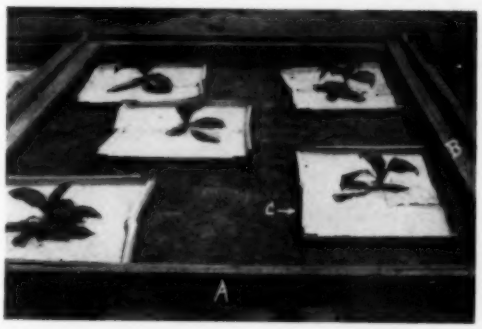


FIG. 2.—Six-square-yard area of a plant bed used for testing the toxicity of insecticides to the tobacco flea beetle. *A*, border board of plant bed; *B*, board upon which paradichlorobenzene crystals were placed, when used; and *C*, plant collar used as an aid to counting beetles. Florence, S. C., 1939.

Table 2.—Results of cloth-bag tests in plant beds with plant-bed covers of different mesh showing the number of beetles treated and the average percentages of dead found 72 hours after treatment, Florence, S. C., 1939.

Ounces of Paradichlorobenzene per Square Yard	Threads per Square Inch of Plant-Bed Cover							
	38 by 38		48 by 48		64 by 64		68 by 72	
	Beetles		Beetles		Beetles		Beetles	
	No.	Per Cent Dead	No.	Per Cent Dead	No.	Per Cent Dead	No.	Per Cent Dead
0 (Untreated)	50	2.00	—	—	—	—	—	—
1/8	—	—	—	—	50	2.00	—	—
1/4	100	2.00	300	5.67	100	5.00	—	—
1/3	—	—	—	—	—	—	50	0.00
1/2	150	2.67	300	3.33	—	—	—	—
3/4	—	—	—	—	50	6.00	—	—
1	100	7.00	300	5.33	—	—	—	—
2	150	0.00	—	—	—	—	—	—

Plant collars (Fig. 2, *C*) were placed about the base of five thrifty plants in each test area to aid in counting the beetles. An untreated area, comparable to the treated areas, was used as a check in all tests. One hundred beetles were placed on each plant in all test areas when the experiment was begun, and the effectiveness of each treatment was determined by counting the living and dead beetles on each plant and its respective plant collar each morning. After each count the dead beetles were discarded and the living beetles were again released on their respective plants. The results of the three sets of experiments that were carried out with cubé, cryolite, and paradichlorobenzene are presented in table 3.

Table 3.—The results of three experiments in tobacco plant beds where plant collars were used about the base of the sample plants for testing the toxicity of materials to the adult tobacco flea beetle, Florence, S. C., 1939.

Materials Tested (Amount per Sq. Yard)	Plants Used	Beetles Used	Days Tested	Reduction in Living Beetles	Dead Beetles
First experiment					
Check (untreated)	5	500	4	60.2%	1.4%
¼ oz. PDB	5	500	4	48.8	3.2
½ oz. PDB	5	500	4	28.8	5.6
1 oz. PDB	5	500	4	36.4	4.6
Second experiment					
Check (untreated)	5	500	3	57.2%	3.6%
¼ oz. PDB	5	500	3	58.6	5.4
1 oz. PDB	5	500	3	47.2	5.6
80% cryolite (dusted)	5	500	3	87.8	55.8
Third experiment					
Check (untreated)	10	1,000	3	57.6%	6.6%
80% cryolite (dusted)	10	1,000	3	91.0	25.8
1% cubé (dusted)	10	1,000	3	89.2	32.2

In the first experiment several dosages of paradichlorobenzene were compared; in the second a cryolite dust mixture containing 80 per cent of sodium fluoaluminate was substituted for one of the paradichlorobenzene dosages. In both experiments a plant-bed cover containing 38 by 38 strands per square inch was drawn over the test areas at night and removed each morning. These tests showed that paradichlorobenzene killed very few beetles, but some of the beetles were stupefied, which accounts for fewer of them leaving the treated than the untreated plants. The cryolite dust mixture was not only toxic but repellent to the beeltes.

A third experiment was designed primarily to compare the toxicity to the beetle and the protective value to the plant of a cubé dust mixture containing 1 per cent of rotenone with that of a cryolite dust mixture containing 80 per cent of sodium fluoaluminate. The test areas were selected at random and replicated in such a way that all areas were surrounded by tobacco plants in beds on at least three sides. One hundred living beetles were placed on each plant when the experiment was started and no plant-bed cover was used at any time. The dust mixture containing rotenone, considered primarily as a contact insecticide for flea beetles, was applied to each plant after the beetles had been released, whereas the cryolite, essentially a stomach poison, was applied to each plant before the beetles were released. The insecticides were applied to both sides of the leaves of all treated plants at a rate of approximately 10 pounds per 5,000 plants (an acre's planting). By reference to table 3 it may be noted that the dust mixtures containing cryolite or rotenone were superior to the paradichlorobenzene in the percentage killed. The data in colums 5 and 6 of table 3 were computed by the following formulas:

$$\frac{\text{(Number of beetles used)} - \text{(Number of living beetles after treatment)}}{\text{(Number of beetles used)}} \times 100 = \text{Percentage of reduction in number of living beetles.}$$

$$\frac{\text{(Number of dead beetles after treatment)}}{\text{(Number of beetles used)}} \times 100 = \text{Percentage of dead beetles.}$$

Observations during the experiment showed that there was a marked variation in the amount of feeding by the beetles on the plants that received different treatments. Photographs of typical plants were made 6 days after treatment (Fig. 3) to show these differences. The feeding injury to untreated plants is illustrated in Fig. 3, *A;* that to plants treated with a dust mixture containing 1 per cent of rotenone in Fig. 3, *B;* and that to plants treated with the cryolite dust mixture containing 80 per cent of sodium fluoaluminate in

Fig. 3, *C*. It will be noted that the dust mixtures containing rotenone or cryolite gave good plant protection, but the cryolite gave the best protection over a period of 6 days. Attention is called to the fact that the figures given in table 3 are the records for the third day after treatment, whereas the photographs were taken 3 days later.

SUMMARY AND CONCLUSIONS.—Preliminary studies conducted during 1938 showed that concentrations of benzene vapor considered adequate for effective control of blue mold were not toxic to the tobacco flea beetle, *Epitrix parvula* (F.). In similar experiments paradichlorobenzene was variable in its toxicity to the beetle. Because of the interest in beetle control the toxicity of these and other materials was more intensively studied during 1939.

The experiments with paradichlorobenzene applied daily at rates of 0.25, 0.5, 1, and 2 ounces per square yard of plant bed showed that it was not toxic and apparently had little, if any, repellency to the beetle, where ordinary plant-bed cover was used. Where covers hvaing 38 by 38 to 64 by 64 threads per square inch were used, probably resulting in greater concentrations of the vapor, a few beetles were killed, some were made sluggish but continued to feed to some extent on the plants, and the material had some repellent action. From the tests conducted, in which paradichlorobenzene was applied at rates and by methods known to control blue mold, this material cannot be considered as a satisfactory control for flea beetles in plant beds.

Similar tests revealed that benzene exhibited little, if any, toxicity to the beetle.

In the event that the application of benzene or paradichlorobenzene for the control of blue mold had given good plant protection from beetle injury, these treatments still would be of relatively little importance in controlling the beetle throughout the plant-bed season as a whole because there is only a relatively short period, usually after the plants are of good size, when it would be necessary to make applications for the control of blue mold. The most important period for controlling the beetle in plant beds is when the plants are very small, and when blue mold is not likely to be active. Further, the cost of applying either of these materials throughout the plant-bed season would exceed that of insecticides that will give control.

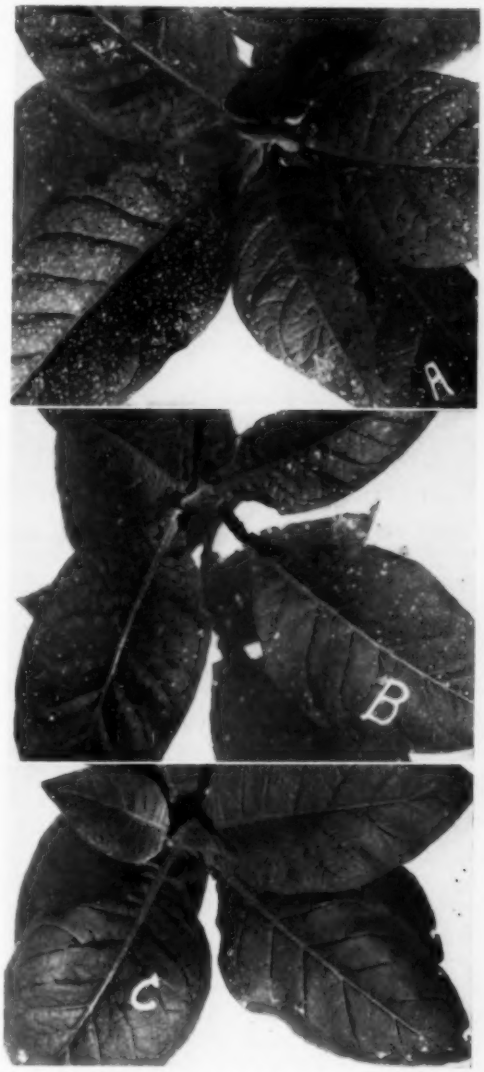


FIG. 3.—Photographs showing the variation in severity of feeding injury by the tobacco flea beetle to tobacco plants 6 days after the plants had received different insecticidal treatments: *A*, a plant that had received no treatment; *B*, one that had been treated with a dust mixture containing 1 per cent of rotenone; and *C*, one that had been treated with a cryolite dust mixture containing 80 per cent of sodium fluoaluminate. Florence, S. C., 1939.

Some late-season tests on individual plants indicated that although a cubé root dust mixture containing 1 per cent of rotenone gave good control, a cryolite dust mixture containing 80 per cent of sodium fluoaluminate gave better plant protection over a period of 6 days.—6-6-40.

LITERATURE CITED

Angell, H. R., A. V. Hill, and J. M. Allen. 1935. Downy mildew (blue mold) of tobacco: its control by benzol and toluol vapours in covered seed-beds. (Australia) Jour. Council Sci. and Indus. Res. **8**: 203–13.

Clayton, E. E. 1938. Paradichlorobenzene as a control for blue mold disease of tobacco. Science (n. s.) **88**(2272): 56.

Clayton, E. E., J. G. Gaines, T. E. Smith, K. J. Shaw, and W. M. Lunn. 1939. Blue mold (downy mildew) disease of tobacco. U. S. Dept. Agr. Farmers' Bul. **1799,** revised.

Gumaer, P. Wilcox. 1938. Control of blue mold of tobacco with benzene vapor. Indus. and Eng. Chem. **30**: 1076–81.

Levin, Clemence. 1940 (in press). Tobacco in plant beds and potatoes as breeding hosts of the tobacco flea beetle. JOUR. ECON. ENT. **33**(3): 473–5.

Lunn, W. M., and J. R. Mattison. 1938. Tobacco investigations; blue mold treatments. S. C. Agr. Expt. Sta. Ann. Rept. **51**: 129–31.

McLean, Ruth, F. A. Wolf, F. R. Darkis, and P. M. Gross. 1937. Control of downy mildew of tobacco by vapors of benzol and of other organic substances. Phytopathology **27**(10): 982–91.

A Progress Report on the Use of Rotenone Dusts for the Control of the Pickleworm and the Melonworm in Alabama

F. S. ARANT, *Alabama Agricultural Experiment Station, Auburn*

Although the pickleworm, *Diaphania nitidalis* (Stoll), and the melonworm, *D. hyalinata* (L.), have been important pests of cucurbits in Alabama and other southern states for many years, no entirely satisfactory control methods have been developed. Numerous references to these insects occur in the literature of American economic entomology between 1860 and 1900 (Henshaw & Banks, 1889–1901). Smith (1911) recommended early planting, trap crops, and other farm practices for the control of the pickleworm and trap crops and lead arsenate sprays for the melonworm. Guyton* found that calcium arsenate dusts were effective against both insects, but burned cantaloupe foliage severely. White (1937) recommended derris-sulphur mixtures containing 0.5 to 1.5 per cent rotenone for use on squash. A commercial insecticide company in 1938 recommended 0.75 per cent rotenone dusts, containing 25 per cent sulphur, for use on various cucurbits.

Field experiments were initiated at Auburn in the summer of 1938 to determine the relative value of various rotenone mixtures in the control of the melonworm and pickleworm. All undiluted rotenone-bearing materials used in these experiments were commercial products guaranteed to contian 4 per cent rotenone. Because of great variations in the size of plots used in different experiments, all yields were expressed as the average number of fruits per 10 hills.

EXPERIMENTS WITH CANTALOUPES AND SQUASH, 1938.—In two preliminary experiments conducted in 1938, one per cent rotenone dusts of derris and talc (1 to 3) and of derris, talc, and *Stimtox D*[1] (1–1.5–1.5) were applied to cantaloupes and squash in separate areas. The pickleworm was more numerous than the melonworm on these plots. The applications were made with a hand dust gun at weekly intervals from the time the first blooms appeared until the fruits were mature.

Table 1.—Results of preliminary dusting experiments on the control of the pickleworm and melonworm, 1938.

	CANTALOUPES			SQUASH		
INSECTICIDE	Av. No. Melons Per 10 Hills	Per Cent Infested	Per Cent Control	Av. No. Fruits Per 10 Hills[2]	Per Cent Infested	Per Cent Control
Derris-Talc-*Stimtox D.* (1-1.5-1.5)	46.7	17.9	80.1	16	0.0	100.0
Derris-Talc (1-3)	26.7	6.2	93.1	16	6.2	88.7
None (checks)	16.7	90.0		11	54.5	

In the experiment with cantaloupes, nine applications of each insecticidal dust were made on each of 6 interspersed hills of the melons; a third group of 6 inter-

* Unpublished data of the Alabama Agricultural Experiment Station.

[1] A commercial diluent containing pyrethrins.

[2] Calculated from an estimated number of hills based on the length of the rows.

spersed hills served as a check. The first, second, third, and seventh dustings were affected by rainfall within 24 hours. The results of this experiment are presented in table 1. The data indicate that both derris mixtures were effective in controlling the pickleworm and melonworm in cantaloupes; only 6 to 18 per cent of the melons were infested on the dusted plants as compared with 90 per cent on the checks.

In the experiment with squash, 5 applications of each dust were made on their respective plots and rainfall within 24 hours after dusting was not a factor. Only 6.2 per cent of the fruits were infested on the plot dusted with derris and talc, as compared with an average of 54.5 per cent on the checks (Table 1). None of the fruits was infested on the plants dusted with the derris-talc-*Stimtox D* mixture.

FIRST EXPERIMENT WITH CANTALOUPES, 1939.—In the first experiment with cantaloupes in 1939, the experimental area was divided into 64 plots, each 10 by 10 feet. Four hills of cantaloupes were planted on each plot and a three-foot alleyway was left between plots. Two tiers of 16 plots each were planted to cantaloupes of the Hasting Imperial variety. The remaining 2 tiers, 32 plots, were planted to honeydew melons. Rotenone dusts were applied by blowing them from a hand dust gun into a cloth-covered frame placed over the plot (Fig. 1). Each dust was allowed to settle for 3 to 4 minutes in order to prevent drifting to adjacent plots when the frame was moved. This method of application permitted dusting even when air currents were fairly strong, but it did not give complete coverage of the lower surfaces of leaves and fruits, particularly when the foliage was dense. This was the only experiment in which this method of applying dust was used.

All dusts applied to cantaloupes in this experiment consisted of a commercial derris powder, containing 4 per cent rotenone, mixed with other ingredients as follows: derris and talc, 1 to 7; derris and talc 1 to 3; and derris, sulphur, and talc, 1–1–2. Each mixture was applied in replicate to eight plots of Imperial cantaloupes and to 8 plots of honeydew melons. There were also 8 checks of each variety. Dusts were applied at the rate of approximately 20 to 30 pounds per acre per application. The first dust was applied just as the plants began to bloom and 8 additional applications were made at intervals of 5 to 8 days. There was no heavy rainfall within 24 hours after any application.

Most of the damage to cantaloupes was caused by the pickleworm, although an occasional specimen of the melonworm was observed. An average of 92.6 per cent of all melons produced on the undusted plants was infested (Table 2). The average infestation on the dusted plots varied from approximately 10 to 40 per cent. The lowest percentage of infestation occurred in melons which received rotenone dusts containing 25 per cent sulphur, but the number of fruits produced was exceedingly low. An average of only 2.2 edible fruits per 10 hills was matured on cantaloupes receiving sulphur dust as compared with 3.1 on the checks and approximately 31 edible fruits per 10 hills on plants treated with derris-talc dusts (Table 2). The latter mixtures caused no burning of foliage

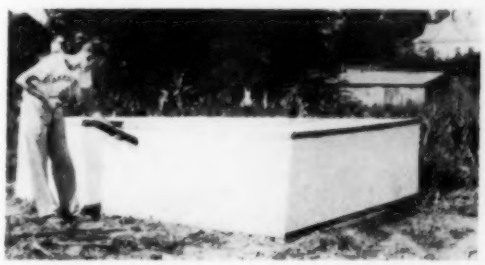


FIG. 1.—Applying derris dust under the covered frame used in the first experiment with cantaloupes in 1939.

Table 2.—Pickleworm and melonworm control from eight replicated treatments of rotenone dusts on cantaloupes. First experiment, 1939.

INSECTICIDE	AV. NO. MELONS PER 10 HILLS	PER CENT OF MELONS INFESTED	PER CENT CONTROL OF INSECTS	AV. NO. EDIBLE MELONS PER 10 HILLS	PER CENT OF MELONS EDIBLE
Derris-Talc (1-3)	39.4	15.9	82.9	31.9	80.9
Derris-Talc (1-7)	45.0	40.3	56.5	31.3[2]	69.5
Derris-Sulphur-Talc (1-1-2)	5.9	10.6		2.2	37.3
None (checks)	38.1	92.6		3.1	8.1

[2] A considerable number of these melons (4.7 per 10 hills), though edible, were infested and damaged slightly, whereas very few edible fruits were infested on the plants receiving 1 per cent rotenone dusts. On the checks, most of the melons were heavily infested and thereby destroyed before reaching the edible stage.

(Fig. 2). The most satisfactory control was obtained from the use of derris diluted 1 to 3 with talc. All applications containing sulphur caused severe burning of foliage (Fig. 3); the few edible melons which reached maturity on the sulphur plots were small, distorted, and of poor quality.

FIG. 2.—Cantaloupe plants which have received several applications of a mixture of derris and talc (1 to 3). There was no injury to the foliage.

The results of the experiment on honeydew melons were uninterpretable because of poor stand, failure of the fruit to ripen, and mechanical injury to the fruit caused by inspection for infestation. It should be pointed out, however, that the sulphur dusts caused only moderate burning of the foliage of this plant.

SECOND EXPERIMENT WITH CANTALOUPES, 1939.—An experiment was conducted on cantaloupes planted about July 1, 1939 in order to determine the effectiveness of 1 per cent rotenone dusts in controlling the pickleworm and melonworm in a late crop. The experimental area was divided into eight plots, each approximately 30×34 feet. Plots 2 and 6 were dusted with a derris mixture, 3 and 7 with timbo, 4 and 8 with cubé, and plots 1 and 5 were not dusted. Since mildews had appeared on the cantaloupe foliage in previous experiments, a copper compound *Cuprocide*, was incorporated into all insecticidal mixtures used in this experiment. One per cent rotenone dusts were prepared by mixing the materials in a ball mill in the following proportions: 4 per cent rotenone powder (derris, timbo, or cubé), 25 parts by weight; talc, 64 parts; flour, 5 parts; *Cuprocide*, 6 parts. Five applications of dust were made with a hand dust gun under field conditions at intervals of 6 to 11 days. Only two dustings were affected by rainfall within 30 hours after they were applied. The rate of application varied from approximately 14 pounds per acre per application when the plants were small to 22 pounds when the plants became large and the foliage dense.

FIG. 3.—Cantaloupe plants which have received several applications of a mixture of derris, sulphur, and talc (1-1-2). Note the withered leaves and bare stems.

In this experiment damage to the fruit was caused almost exclusively by the melonworm. Approximately 54 per cent of the melons on the check plots were infested as compared with no infested melons on the dusted areas (Table 3). In addition to attacking the fruits, the melonworm also fed upon the leaves of the cantaloupes.

The plants on the check plots were defoliated[4] to such an extent that an average of only 3 fruits was produced on 10 hills; on the dusted plots the number of fruits varied from 17.1 to 20.5 on 10 hills. There was no burning of foliage on any plot. A heavy frost killed the plants before the melons were fully ripe.

EXPERIMENT WITH SQUASH, 1939—Five plots of squash, each containing an average of approximately 28 hills, were used in this experiment. One per cent rotenone dusts consisting of flour mixed with derris, timbo, and cubé, respectively, were applied to their separate plots. Five dustings were made at intervals of 7 to 11 days. All three materials gave satisfactory control,

Table 3.—Control of the melonworm and pickleworm in cantaloupes with 1 per cent rotenone dusts. Second experiment, 1939.

INSECTICIDE	NO. OF HILLS	FRUITS PRODUCED		PER CENT INFESTED
		Total No.	Av. No. Per 10 Hills	
Derris-Talc-Flour-*Cuprocide* (25-64-5-6)	41	84	20.5	0.00
Timbo-Talc-Flour-*Cuprocide* (25-64-5-6)	37	76	20.0	0.00
Cubé-Talc-Flour-*Cuprocide* (25-64-5-6)	35	60	17.1	0.00
None (checks)	37	11	3.0	54.5

but cubé appeared to be slightly inferior to the other two (Table 4). An average of 48.5 per cent of the squash was infested on the check plots and some defoliation occurred. The damage was caused princi-

[4] Cucumber beetles, particularly *Diabrotica balteata* Lec., were responsible for some of the damage to the foliage.

pally by the melonworm, as very few pickleworm larvae were present.

SUMMARY.—Derris-talc dusts containing 1 per cent rotenone were effective in controlling the pickleworm and melonworm on small field plots; the control in

Table 4.—Control of the melonworm and pickleworm in squash with 1 per cent rotenone dusts, 1939.

INSECTICIDE	FRUITS PRODUCED[5]		PER CENT INFESTED	PER CENT CONTROL
	Total No.	Av. No. Per 10 Hills		
Derris-Flour (1-3)	110	39.3	3.6	92.5
Timbo-Flour (1-3)	66	41.3	6.1	87.4
Cubé-Flour (1-3)	73	30.4	9.6	80.2
None (checks)	165	23.9	48.5	

cantaloupes varied from 83 to 100 per cent and in squash from 89 to 100 per cent. A derris dust containing 25 per cent sulphur was effective against the insects, but caused such severe burning to cantaloupe foliage that an average of only 2.2 ripe edible fruits per 10 hills was produced as compared with 3.1 on the checks and approximately 31 edible melons per 10 hills on plants dusted with derris and talc. Derris mixtures containing 0.5 per cent rotenone were less effective than dusts containing 1 per cent rotenone. Cubé appeared to be inferior to timbo and derris. Heavy applications of dusts were made, approximately 15 to 30 pounds per acre, and no attempt was made to determine the minimum effective rate of application. —6-6-40.

[5] Only fruits of edible size were counted.

LITERATURE CITED

Henshaw, Samuel and Nathan Banks. 1889–1901. Bibliography of the more important contributions to American economic entomology. U. S. Department of Agriculture Div. of Entomology. Parts I–VII.

Smith, R. I. 1911. Two important cantaloupe pests. N. C. Agr. Expt. Sta. Bul. **214**, pp. 105–46.

White, W. H. 1937. Recommendations for the control of insects attacking certain vegetables, small fruits, and tobacco. U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine. Mim. Cir. E-376, pp. 9–10.

Curculionidae, Bruchidae, Lepidoptera, and Their Parasites, Infesting the Seed Pods of Cowpea and Various Wild Plants*

THEODORE L. BISSELL, *Georgia Experiment Station, Experiment, Georgia*

In 1938 the writer published a report on the host plants of a number of Curculionidae and Bruchidae that had been discovered in the course of work on the cowpea curculio. Several additional records made in the two seasons following are reported here. Short descriptive notes of the insects and plants are added to aid in quick recognition of the species.

All collections were made in Spalding County, Georgia, unless stated otherwise. Determinations of insects have been checked by specialists in the Division of Insect Identification, U. S. Bureau of Entomology and Plant Quarantine and the plants were identified by Dr. W. A. Jenkins, Georgia Experiment Station.

Chalcodermus aeneus Boh.—In 1939 various species of wild legumes were planted in uniform plots to observe growth and insect infestation. These included *Strophostyles umbellata* (Muhl.) Britton, a species that grows wild in central Georgia, and *S. helvola* (L.) Ell., a coarser species, which is said by Small (1933) to inhabit river banks. The seed of *S. helvola* was received from the Soil Conservation Service, Americus, Georgia, which organization is testing the plant as a cover crop. Although the cowpea curculio infested the pods of both species, it was four times as numerous in *S. umbellata*, which has already been reported as a host. Pods of *S. umbellata* usually contained one larva of *C. aeneus;* rarely there were two. The pods contained 4 to 11 seeds. The number of seeds consumed by an individual grub was variable but about 5 or 6 are necessary for full development. The height of infestation of *Strophostyles* pods occurred about the first of October in both 1938 and 1939.

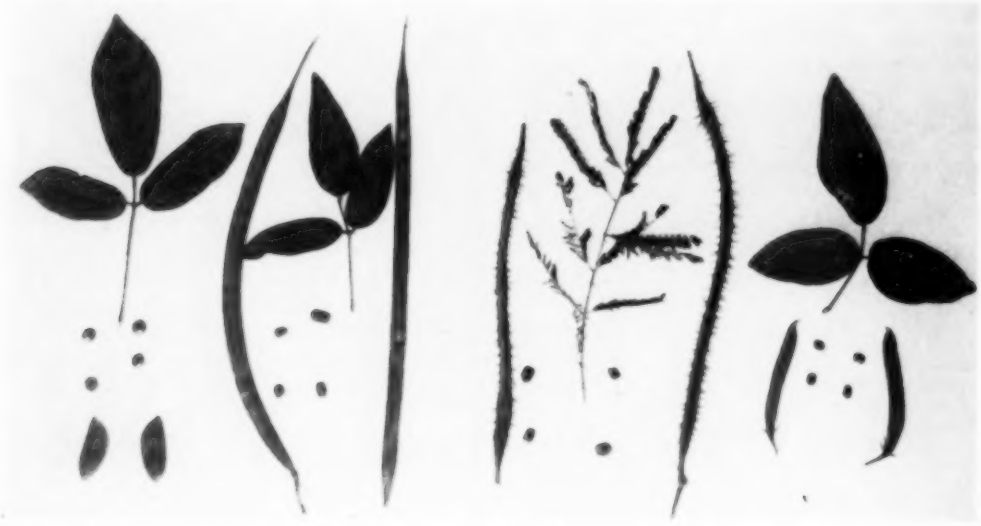


FIG. 1.—Leaf, pod, and seed specimens of leguminous hosts of *Chalcodermus inaequicollis* Horn. Left to right: *Rhynchosia erecta, Bradburya virginiana, Leptoglottis Nuttallii,* and *Galactia volubilis.*

Chalcodermus inaequicollis Horn was bred from the pods of *Rhynchosia* (*Dolicholus*) *erecta* (Walt.) DC. and from *Leptoglottis* (*Schrankia*) *Nuttallii* DC. Four leguminous host plants, two of which were reported in 1938, are now known for this weevil. Photographs of the host plants are shown in figure 1. It will be noted that the pods of the four differ noticeably in size and structure, but the seeds are similar in

* Paper No. 71, Journal Series, Georgia Experiment Station.

size. *Rhynchosia erecta* is an upright shrubby plant; *Bradburya* and *Galactia* climb on others for support; while *Leptoglottis*, a thorny plant with sensitive leaflets, trails along the ground.

Blatchley and Leng (1916) reported taking this weevil from the leaf axils of a thistle, *Carduus spinosissimus* Walt., in Florida, but did not give a breeding host.

Time of infestation of the various hosts depends, of course, on the fruiting period. Grubs developed in pods of *Leptoglottis* after the latter have left the plant pod and entered the soil.

The remaining parasites kill the host larvae in the pods and emerge thereform. Species in the table marked "X" have been definitely found to be parasites of *Chalcodermus*, either by rearing from larvae caged in soil or by dissection from infested seed. *Eupelmus cyaniceps* variety *amicus* Gir. was found in one case as a secondary parasite of another species of Hymenoptera in cowpeas. Judging by

Table 1.—Parasites of *Chalcodermus* larvae in leguminous plants in Georgia.

PARASITE	HOST AND ITS HOST PLANT					
	C. aeneus	Host plant	*C. inaequicollis*	Host plant	*C. collaris*	Host plant
Myiophasia globosa Tns.	X	Cowpea	X	*Leptoglottis*	X	*Chamaecrista robusta* and *C. procumbens*
	X	Stringbean				
Triaspis curculionis var. *rufus* (Riley)	X	Cowpea				
Triaspis sp. (undescribed)	X	Cowpea	X	*Leptoglottis*		
Microbracon mellitor (Say)	X	Cowpea	X 1	*Rhynchosia*		
Microbracon variabilis (Prov.)					X	*C. robusta*
Eurytoma tylodermatis (Ashm.)	X	Cowpea				
Eupelmus cyaniceps var. *amicus* Gir.	?	Cowpea	X	*Rhynchosia*		
Zatropis incertus (Ashm.)	X	Strophostyles spp.	X 1	*Leptoglottis*		
	X	Cowpea				
Tetrastichus doteni (Cwfd.)					H 1	*C. robusta*

X Relation of host and parasite certain.
? Parasite bred from host plant, insect host uncertain.
X 1 Hyperparasite on Microbracon?, one specimen.

early in July in 1938 and 1939. *Rhynchosia* is found infested in late July and in August. *Bradburya* and *Galactia* pods with grubs were collected from August to October. Over the several years the earliest seasonal collection of infested pods was July 4, the latest October 21.

Grubs emerge from the pods within a week after collection and seek soil in which to burrow and pupate. The earliest grubs emerged July 5; the latest October 28. Adults from these matured July 25 to December 3, that is, 20 to 36 days after the grubs burrowed into the soil. It is likely that there are two generations of this weevil yearly.

Parasites of *Chalcodermus* larvae which have appeared in the course of this work are given in table 1. *Myiophasia globosa* has been the most abundant species and in cowpeas it kills about twenty per cent of the curculio grubs that leave the pods. This tachinid fly and the two species of *Triaspis* (Braconidae) emerge from larvae emergence dates it appears to be parasitic on *C. aeneus* but it may also attack caterpillars and bruchids in the pods. *Zatropis incertus* (Ashm.) was found positively on *C. aeneus* only once when a third instar grub was parasitized. However, more than 50 specimens have been bred from various lots of cowpeas, usually emerging 12 to 25 days after picking, and the curculio is the most likely host. *Z. incertus* was the only parasite definitely found on *C. aeneus* in pods of *Strophostyles*.

Myiophasia globosa is shining black and bristly. *Triaspis* sp. is black with longitudinal grooves on the abdomen and the legs are yellow, while *T. curculionis* var. *rufus* has a red thorax and is larger. *Microbracon mellitor* is pale brown or reddish brown and sometimes has black patches on the adjoining parts of thorax and abdomen. *Eurytoma* is black with coarse pits on the thorax but has a smooth abdomen. *Eupelmus* is greenish bronze and hairy, and the female has a V-shaped impression

on the thorax. *Zatropis* is green or coppery with sparse white hairs. It is much smaller than any of the other parasites of *Chalcodermus aeneus*.

Three species of Hymenoptera reported earlier (Bissell 1938), *Callimome anthomyiae* (Ashm.), *Galeopsomyia* sp., and *Zatropis coeliodis* (Ashm.), have not been encountered again and their hosts are not known.

Apion delta Buch.—This curculionid is about the same size as *A. griseum* Smith but differs from that species in having red legs, brown hair on the back, and three white spots of hair around the scutellum. It was bred from the pods of *Croton glandulosus* L. of the family Euphorbiaceae. Each of the spherical pods contains three seeds but only one was used by a given developing weevil. A lot of 128 pods contained 15 adult and immature weevils, and 14 parasitized weevil larvae.

Three species of hymenopterous parasites were dissected from the seed pods of *Croton* and found on the larvae of *Apion delta*. These were *Trimeromicrus* sp. (an undescribed species near *T. maculatus* Gahan), a striking chalcid with green spots or stripes on a black thorax; *Eupelmus allynii* (French), the male with yellow femurs quite different from the female; and *Heterospilus* sp. The first named parasite was the most abundant.

Apion rostrum Say, the largest species of the genus known to the writer, was found June 22 in pods of *Baptisia tinctoria* (L.) R. Br. at Tifton, Georgia. Weevils were then in the adult stage and no pod contained more than one insect. About two-thirds of the seeds were consumed in each infested pod.

Acanthoscelides alboscutellatus (Horn), Bruchidae, was found in the pods of *Ludwigia alternifolia* L., "seedbox," of the evening primrose family. The seeds of this plant are minute and many are contained in each of the four compartments of the pod. Each weevil was found in a cell with walls formed of closely compacted seeds and excrement. The chalcid *Eupelmus cyaniceps* var. *amicus* emerged from the *Ludwigia* pods along with the bruchids.

Acanthoscelides distinguendus (Horn).—This gray checkered beetle, rather broad, emerged from August to November from the pods of two species of legumes, *Rhynchosia erecta* (Walt.) DC. and *R. intermedia* (T. & G.) Small. Blatchley, in "Coleoptera of Indiana," states that this bruchid breeds in the pods of *Cracca virginiana* L., but in view of Yip's work (Yip 1936) with this plant, Blatchley possibly had reference to *A. obsoletus* Say, which Mr. J. C. Bridwell indicates (in correspondence) is similar to *A. distinguendus*.

Acanthoscelides schrankiae (Horn), a small bruchid with red fore and mid legs and an almost solid gray back developed in pods of the sensitive brier, *Leptoglottis* (*Schrankia*) *Nuttallii* DC. In several collections of pods this insect was about as common as the grubs of *Chalcodermus inaequicollis;* however, in one lot there were bruchids only, which had destroyed about one-third of the seeds. Emergence occurred from July 15 to October 5.

Acanthoscelides longistilus (Horn), the smallest bruchid in this series, emerged from the seed of *Lespedeza* sp. (*L. frutescens* (L.) Britton or *virginica* (L.) Britton), and from *L. hirta* (L.) Ell. collected at Mitchell, Georgia, in October, 1937. From the same lot of seed came the weevil, *Apion decoloratum* Smith, and three chalcids, *Zatropis incertus* (Ashm.), *Catolaccus* sp. (undescribed), and *Tetrastichus* sp. (undescribed). The exact host of any of these Hymenoptera is not known.

Callosobruchus maculatus (Fab.).—The cowpea weevil is associated with peas in storage but infestations often begin in the field. A lot of blackeyed cowpeas picked July 20 and caged in the pods, produced weevils beginning August 7. Parasites began emerging the latter part of August but they were not distinguished from parasites of the curculio until some time later. Three chalcids were later definitely found to be parasites of *Callosobruchus*. These were *Bruchobius laticeps* (Ashm.) coppercolored and robust; *Lariophagus texanus* Cwfd., black; and *Aplastomorpha calandrae* (How.), green, with conspicuous fine white hair, and the smallest of the three. The number of *Lariophagus* per weevil grub ranged from one to eight and it appeared that the number varied directly with the size of the host. The other two parasites always occurred singly. The degree of parasitism by the three chalcids in the single lot of cowpeas was about equal. In a random lot of 24 seeds they killed 57 grubs or 43 per cent of the total number.

No positive case was discovered in which the parasites of *Chalcodermus aeneus*, listed in Table 1, attacked *Callosobruchus* or in which parasites of the latter attacked the curculio, although curculios and weevils often infested the same peas.

Caterpillars of two moths, the Indianmeal moth and the Angoumois grain moth, fed and matured in dry cowpea pods. In every case observed they entered the cells in the peas vacated by the cowpea curculio and usually pupated in these places. It appeared that the caterpillars consumed the frass of the curculio but may have also eaten cowpea tissue.

Ulophora grotei Rag.—A small moth of the family Pyralididae was bred from pods of *Cracca spicata* (Walt.) Kuntze, collected in Spalding County and from *Cracca virginiana* L., collected in Glascock County. The caterpillars, which were quite common in some lots, were white or yellow when small and blue or bluish-green when mature. Pupation occurred in the soil in well made cocoons a little below the surface. Moths were obtained September 22 to November 20.

Yip (1936) found caterpillars of *Ulophora tephrosiella* Dyar in pods of *Cracca virginiana* which were collected in several parts of the United States. Descriptions of three species of *Ulophora* were given by Forbes (1923).

There were two parasites of the *Ulophora grotei* caterpillars, *Eupelmus cyaniceps* var. *amicus* and *Heterospilus* sp. (undescribed), the latter being found the more commonly in collections from both Spalding and Glascock Counties. Yip also found a new species of *Heterospilus*, but we do not know that they are the same.

Myelois venipars Dyar.—The navel orange worm fed in pods of honey locust, *Gleditsia triacanthos* L., and moths emerged in January in the laboratory. This insect is known to be a scavenger.—7-13-40.

LITERATURE CITED

Bissell, Theodore L. 1938. The host plants and parasites of the cowpea curculio and other legume infesting weevils. JOUR. ECON. ENT. **31**: 534–6.

Blatchley, W. S. and C. W. Leng. 1916. Rhynchophora or weevils of North Eastern America. Indianapolis.

Forbes, William T. M. 1923. The Lepidoptera of New York and neigboring states. Cornell University Memoir **68**, 729 pp.

Small, John Kunkel. 1933. Manual of the southeastern flora. New York.

Yip, Jethro S. 1936. Insect damage to seeds of *Cracca virginiana* L. JOUR. ECON. ENT. **29**: 622–9.

Lateral Migration and Depth of Pupation of the Larvae of the Primary Screwworm *Cochliomyia americana* C. and P.

BERNARD V. TRAVIS, E. F. KNIPLING, and ARTHUR L. BRODY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The distance that larvae of the primary screwworm, *Cochliomyia americana* C. and P., will migrate from the place where they have dropped to the ground and the depth at which they pupate in the soil were studied under field conditions during the fall of 1935 and the spring of 1936 at Valdosta, Ga. These tests were conducted to determine the advisability of further studies on methods of control for larvae and pupae of the screwworm in carcasses of animals or in the soil near infested animals. Tests on methods of controlling larvae and pupae in the soil and carcass have been conducted by Brody & Knipling (1940).

Data on the distance that screwworms migrate laterally and the depth at which they pupate are of practical significance in control campaigns, as well as of biological interest. Infested animals usually hide in some secluded spot for several days before their death, and frequently the larvae have dropped in the soil before the animal is found. Tests have indicated that larvae of the primary screwworm begin to migrate from a carcass immediately after death of the infested animal and that practically all have left the carcass within 48 hours. The destruction of such larvae and pupae may prove to be a worth while control measure, but before such measures of control are recommended, the size of the area to be treated and the depth to which the treatment should penetrate the soil must be known.

The burning of carcasses of animals that have died of screwworm infestations has been recommended for some time (Bishopp *et al.* 1917), and recent investigations by Brody & Knipling (1940) have shown that improved methods of burning and the application of certain chemicals to the soil around the carcass are effective in destroying larvae and pupae of the primary screwworm as well as those of blowflies that normally feed on dead tissue.

Table 1.—Distribution of *Cochliomyia americana* pupae and adults within concentric circular areas around area into which larvae had dropped from infested animals.

Diameter of Area, Feet	Adults		Pupae		Adults and Pupae, Per Cent
	Number	Per Cent	Number	Per Cent	
1	208	28.3	253	39.4	33.4
3	508	69.0	268	41.8	56.3
5	19	2.6	116	18.1	9.8
7	1	.1	5	.7	.5
Total	736	100.0	642	100.0	100.0

LATERAL MIGRATION.—Two sets of experiments were conducted to determine the lateral distance that the larvae of the primary screwworm might migrate. In test 1, which was representative of larvae dropping from a live animal, an infested goat was confined in a cage so constructed that the mature larvae leaving the animal dropped to the ground in an area 1 foot in diameter. The larvae dropped on a sandy-loam pasture that had a moderate covering of Bermuda grass. After the larvae had pupated, a series of metal hoops, 8 inches high and 1, 3, 5, and 7 feet in diameter, was placed in concentric circles over this area, with the inner circle around the spot where the larvae had dropped. Screen was soldered to the tops of the hoops, making each circle a cage to confine the emerging flies.

In test 2, which was representative of larvae dropping from a dead animal, a goat infested with mature larvae was killed and placed on the ground where the soil conditions were the same as in test 1. After the larvae had dropped to the ground, the carcass was removed and the area laid off in concentric circles of the same diameter as those in test 1, with the center directly under the hip region of the carcass, in which the screwworms were located. After all larvae had pupated, the soil from each circle was sifted and the pupae counted.

The results indicate that for the type of soil on which these tests were made the larvae do not migrate far from the point where they drop to the ground, since over 89 per cent pupated within 18 inches of the center of the area where they had dropped (Table 1). Thus it is believed that the area around an animal that has died of screwworm infestation is sufficiently small to warrant the use of soil treatments.

In the field it had appeared that when *Cochliomyia americana* larvae migrated from a dead animal they tended to crawl under the carcass to complete their development. A goat infested with mature larvae in the region of the hip was killed and placed in a sandy-loam pasture with a moderate covering of Bermuda grass. After the larvae had pupated, the soil from the area covered by the body of the animal and from between concentric contours 1 foot apart was sifted. It was found that 69 per cent of the larvae pupated under the body of the goat (Table 2).

Table 2.—Distribution of *Cochliomyia americana* pupae with reference to location of carcass from which larvae had dropped.

Area	Number of Pupae	Percentage of Total Pupae
Within contour of carcass	428	68.7
Within contour 1 foot from carcass	184	29.5
Within contour 2 feet from carcass	11	1.8
Total	623	100.0

DEPTH OF PUPATION.—The depth of pupation was tested under various soil conditions by allowing mature larvae to drop naturally from confined live infested goats, from animals killed and placed on the ground in the desired locations, and also by dropping mature larvae removed from collection cages on test plots in various locations. Test areas where larvae were allowed to pupate were as follows: A lane where the soil was well packed and the vegetation sparse except for a heavy Bermuda grass sod; a sandy-loam pasture; a barn lot that was a sandy loam with a large quantity of pecan hulls mixed in the soil and manure; wet sandy soil near a

pond; muck in a cypress swamp; and dry loose sand under a house.

The data for the various locations, except for the dry sand under a house, are not presented separately because they did not differ greatly.

In a preliminary test with larvae that had dropped naturally from a live goat the soil in which the larvae had pupated was removed in horizontal layers 1 inch thick. All the 291 pupae were found to be in the top 2 inches of the soil, 97.6 per cent being in the top inch and 2.4 per cent in the second inch.

In subsequent studies the soil was sliced vertically with a sharp knife so that the depth of the pupae might be more accurately measured. The distance was measured from the highest point of each pupa to the top of the ground and to an accuracy of one-fourth of an inch. Little difference was found between the average depth of pupation of larvae that had dropped naturally from a host and those that had been removed from collecting cages and placed on the soil. The differences were significant statistically, but for practical field use they were not sufficiently pronounced to alter recommendations for the treatment of these pupae. Pupation occurred deeper in loose dry sand under a house than in soil exposed to the weather (Table 3). No pupae were found more than $1\frac{1}{2}$ inches below the surface of the ground. This habit of pupation places the majority of the pupae within reach of soil treatments.

It was noted that larvae tended to pupate in clumps of vegetation, where such was present, and that pupation was slightly deeper where the vegetation was more sparse. In heavy Bermuda grass sod the larvae frequently pupated in the crown of the grass plants or among the roots rather than in the bare soil between the clumps of grass. The larvae migrated farther where there was no vegetation than where the vegetation was dense. In small cages containing moist soil pupation occurred at much greater depths than in the field.

A study of the orientation of the pupae in the soil showed 66 per cent in a vertical position, 30 per cent at an angle between vertical and horizontal, and 4 per cent in a horizontal position. When the pupae were not lying in a horizontal position, the anterior ends were pointed up.

Table 3.—Depth of pupation of *Cochliomyia americana*.

Test	Percentage of Larvae Pupating at Indicated Depths						Total Pupae
	0 to $\frac{1}{4}$ Inches	$\frac{1}{4}$ to $\frac{1}{2}$ Inches	$\frac{1}{2}$ to $\frac{3}{4}$ Inches	$\frac{3}{4}$ to 1 Inches	1 to $1\frac{1}{4}$ Inches	$1\frac{1}{4}$ to $1\frac{1}{2}$ Inches	
Larvae allowed to drop naturally from live host	39.0	45.5	10.5	3.5	1.5	0	200
Larvae from collection cages placed in soil exposed to weather	49.6	46.4	4.0	0	0	0	224
Larvae from collection cages placed in dry sand under a house	0	0	14.0	58.0	26.0	2	50

CONCLUSIONS.—Since most of the larvae leave a carcass rather promptly after the death of the infested animal, and since they pupate near the carcass and also near the surface of the soil, the treatment of soil beneath and in the vicinity of an animal that has died from screwworm infestations may prove more important for the control of the primary screwworm than the destruction of the carcass itself. The treatment should extend at least $2\frac{1}{2}$ feet in all directions from the place where the larvae have dropped and should be effective at a depth of approximately 1 inch.

SUMMARY.—Studies were conducted during the fall of 1935 and the spring of 1936 at Valdosta, Ga., to ascertain the distance that larvae of the primary screwworm (*Cochliomyia americana* C. and P.) will migrate from the place of dropping to the ground and the depth at which they pupate in the soil. To determine lateral migration an infested animal was so caged that larvae which emerged from the wound dropped to the ground in an area one foot in diameter. Likewise infested carcasses were so placed that the larvae reached the ground on a small area. The distances these larvae travelled were de-

termined by using a graduated series of metal hoops 1, 3, 5, and 7 feet in diameter with the smallest surrounding the area on which the larvae dropped. Adults which emerged from the areas between these hoops were trapped, or the soil of these areas sifted to find the pupae. Depth of pupation was tested by allowing mature larvae to drop naturally on various types of soil, and by artificial placement in similar situations, then noting the depth to which they burrowed before pupation. The results indicate that 90 per cent of these larvae pupate within a radius of 18 inches from where they drop, and that under field conditions practically all larvae pupate in the soil within one-half inch of the surface. Most of the pupae are in a vertical position in the soil.—6-6-40.

LITERATURE CITED

Bishopp, F. C., J. D. Mitchell, and D. C. Parman. 1917. Screw-worms and other maggots affecting animals. U. S. Dept. Agr. Farmers' Bul. **857.**

Brody, Arthur L. and E. F. Knipling. 1940. Methods of destroying blowfly larvae and pupae in carcasses and in soil. JOUR. ECON. ENT. **40** (4): 662-5.

The Nutritional Requirements of Screwworm Larvae

ROY MELVIN and RAYMOND C. BUSHLAND, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The screwworm, *Cochliomyia americana* C. & P., is one of the most destructive pests of livestock in this country. In nature the larvae live as obligatory parasites on warm-blooded animals, having never been found to complete their growth normally on cold-blooded animals or on carcasses or other non-living media. The earlier work on the biology and methods of control was considerably handicapped by the time-consuming and expensive procedure of rearing the larvae on living animals. By a careful study of their nutritional and temperature requirements it has been possible to develop a method of rearing the larvae on artificial media (Melvin & Bushland 1936) and this has been of distinct importance in furthering research work on larvicides and on many other aspects of the screwworm problem. Since the discovery that these larvae could be reared on artificial media, further studies have been made on their nutritional requirements. The results of these studies, together with notes on incidental observations, are presented herein.

In the course of this work many modifications and improvements in the medium have been made. During the past year the following formula has been used with success: 1 liter of water, 6 cubic centimeters of formalin (39 per cent formaldehyde), 1 kilogram of finely ground lean beef, and 500 cubic centimeters of citrated beef blood (3 grams of sodium citrate per liter of blood). The ingredients are thoroughly mixed, in the order given, in a No. 2 galvanized tub, approximately 15 inches in height by 2 feet in diameter. The rearing tub is kept in a warm room (temperature range 85 to 100 degrees F.).

Newly hatched larvae are placed on the medium and begin feeding immediately. They are allowed to feed for 3 days and are then transferred to a tub of fresh medium where they feed for 3 or 4 days more before completing larval growth. When a tub is overstocked with larvae, the transfer must be made sooner. During the first 3 days several thousand larvae may be grown in one rearing tub, but during the second 3 days about 2,000 larvae will exhaust the food supply of a fresh tub.

Transferring of larvae is easily accomplished since they are gregarious in their feeding habits. They feed as a group and move slowly across the tub, leaving the medium viscous and dark.

On about the sixth day some of the larvae cease feeding and begin to migrate. The culture tub is then tilted over another tub containing approximately one inch of moist sand. The larvae crawl from the rearing tub and fall to the sand, which they enter to pupate. About 2 days are required for a culture to finish feeding and leave the rearing tub after the larvae begin to migrate.

The larvae and pupae are sifted from the sand tub and placed in buckets of

moist sand for development of the pupae.

Larvae may be reared at a cost of less than 50 cents a thousand, which is much cheaper than rearing larvae on live animals. Considering humaneness, the reduction of objectionable odors, and the conservation of laboratory space, media rearing is to be preferred to animal rearing of screwworms.

In the development of the method described the breeding stocks have been carried for 88 consecutive generations, about 4,000 larvae having been reared per week over a period of 4½ years. During this period there has been no apparent change in the normal biology of the insect or its physiology and morphology.

The formula given does not need to be followed strictly for satisfactory results. The amount of formalin, however, is important. Bacterial decomposition renders the medium unsuitable for larval development. Formalin at the rate of 6 cubic centimeters per tub greatly inhibits decomposition, but at lower concentrations is insufficient to prevent spoilage of the medium and at higher concentrations retards larval growth. Ten grams of sodium benzoate has been used in lieu of 6 cubic centimeters of formalin, but is not quite so satisfactory.

In place of beef blood, the blood of goats, sheep, and hogs has been used successfully. Larvae have been reared satisfactorily on ground muscle of sheep, hogs, chickens, rabbits, sparrows, doves, and catfish.

Larvae have been reared on media containing ground beef heart, but they did not mature on beef or pig liver. Larvae will develop in a medium containing three parts of liver to one part of ground beef, but they are abnormally small even when equal parts of beef muscle and liver are used. Whatever meat is used, it should be as lean as possible, as fat appears to smother the larvae.

The volume of the medium can be regulated according to the number of larvae being reared. Larvae have been grown individually and in groups of ten in 10-cc. vials. Thousands of toxicity tests have been conducted using 150 cc. of medium in wide-mouth pint mason jars.

Regardless of the size of the container, the medium should fill it to a depth of approximately one inch. If deeper some of the food is wasted and if shallower the medium tends to become too dry for the larvae.

Considerable study was given the matter of rearing screwworm larvae on sterile media. Although no method was devised for rearing large numbers of larvae aseptically, several media were developed that are applicable where limited numbers are desired. One of the most satisfactory of these is described briefly below, together with the technique employed.

Fifty cubic centimeters of a mixture containing 25 per cent of egg yolks, 25 per cent of whole sweet milk, 1 per cent of agar-agar, and 49 per cent of water was placed in a 250 cc. erlenmeyer flask, which was plugged with cotton and autoclaved. After the mixture had cooled, *Cochliomyia americana* eggs were introduced aseptically. The eggs had been sterilized in a solution of alcoholic mercuric chloride, by a method which was a slight modification of that used by White (1937). In many tests the flasks were kept at a temperature of 89 to 94 degrees F. The larvae matured rather rapidly and in many cases crawled up the side of the flask and escaped or pupated in the cotton plug. Although tests for aerobic and anaerobic bacteria were negative during the development of the larvae, these tests were often positive after several of the larvae had escaped, and no sterile pupae were obtained. Nevertheless, this medium and method should be adaptable to certain types of studies. In this connection it is worthy of note that the sterile medium had a sweetish applelike odor even after the larvae had completed development.

By a slight modification of the above technique a method was developed whereby a limited number of sterile pupae and flies could be obtained. The method consisted of placing the medium in a 50-cc. beaker and then placing the beaker in a wide-mouth jar containing 1 inch of washed sea sand. A short piece of copper tubing 1 inch in diameter was soldered into the jar lid and plugged with cotton. The jar was sealed and the set-up autoclaved. After cooling, sterilized eggs were added through the copper tubing. As the larvae matured they migrated from the beaker and were trapped in the sand, where they pupated and developed into flies.

In tests to determine the effect of adding various materials to the nutritional medium the following results were obtained: Dextrose and sucrose at a concentration of 2.6 per cent in the medium permitted larvae to develop to maturity, but at a concentration of 6.7 per cent were lethal. Copper sulfate at a concentration of 0.03 per cent was apparently harmless to the larvae, but at 0.07 per cent was lethal. Boric acid killed young larvae at a concentration of 0.33 per cent but did not affect them at a concentration of 0.17 per cent. Arsenic trioxide at 0.03 per cent was lethal but at 0.003 per cent produced no marked effects on the larvae. Phenothiazine was not toxic at a concentration of 0.03 per cent but was lethal at 0.05 per cent.

The fact that screwworm larvae develop in these media in spite of the presence of relatively large amounts of insecticides demonstrates that the media possess an abundance of the nutritive materials necessary for growth.

In connection with these studies attempts were made artificially to infest animals of unknown susceptibility to the screwworm. When introduced into fresh wounds in the crow, English sparrow, and garden toad, larvae completed their development. The record concerning the garden toad is of special interest since the host is a cold-blooded animal. Several attempts to rear screwworms on horned frogs were unsuccessful.

SUMMARY.—In rearing larvae of the screwworm, *Cochliomyia americana* C. & P., for experimental purposes an artificial medium consisting of 1 liter of water, 6 cc. of formalin (39 per cent formaldehyde), 1 kilogram of finely ground lean beef, and 500 cc. of citrated beef blood (3 grams of sodium citrate per liter of blood) has been successfully used. Variations of this formula are possible but the proportion of formalin should not be changed. For rearing large numbers of larvae a No. 2 galvanized tub makes a convenient vessel for holding the material. Another tub containing sand is used for the full grown larvae, which pupate in the sand. In this way larvae may be reared at a cost of less than 50 cents a thousand, which is much cheaper than rearing them on live animals.

Considerable study was given to the matter of aseptic rearing of larvae. No method was devised for rearing large numbers of larvae aseptically, but several media were developed that are applicable where limited numbers are used. These and the technique for their use are described.

Under laboratory conditions screwworm larvae were reared on several kinds of animals, including the common garden toad. 6-19-40.

LITERATURE CITED

Melvin, Roy, and R. C. Bushland. 1936. A method of rearing *Cochliomyia americana* C. & P. on artificial media. U. S. Dept. Agr., Bur. Ent. & Plant Quar. **ET:88.** (Multigraphed.)

White, G. F. 1937. Rearing maggots for surgical use. In Culture Methods for Invertebrate Animals, a compendium prepared by Section F of the American Association of Economic Entomologists, pp. 418–27.

Melissopus latiferreanus as a Pest of Filberts in the Northwest

S. M. DOHANIAN, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Among the insects that attack the filbert in the Pacific Northwest *Melissopus latiferreanus* (Walsingham),[1] referred to in this paper as the filbert worm, has caused the growers the greatest concern on account of its direct damage to the nuts and the expense involved in sorting the infested nuts from the sound ones. Although the actual losses for the most part have not been serious, several locally severe infestations have developed, demonstrating the potential importance of the insect. The filbert worm has been under observation by the Entomology Department of the Oregon Agricultural Experiment Station for a number of years and that agency is now conducting experimental control tests against it (Thompson 1938). This

[1] Order Lepidoptera, family Olethreutidae, subfamily Laspeyresiinae.

paper is presented because the preliminary investigations on the biology of the insect, conducted at the Eugene, Oregon, laboratory of the Bureau of Entomology and Plant Quarantine, have brought to light certain interesting facts and trends which appear to be worthy of record.

THE FILBERT INDUSTRY.—Although the early settlers in the Pacific Coast States planted an occasional filbert tree to obtain nuts for home use, commercial orchards were not planted until about the beginning of the present century. During the first two decades of this period the growth of the industry was indeed slow, a recent census showing approximately 4,500 trees as the total planted prior to 1920. Its expansion since, however, has been phenomenal, it being estimated that today more than 1,100,000 trees are to be found in the filbert orchards of the Pacific Northwest. Last year the Bureau of Agricultural Economics of the United States Department of Agriculture predicted that the increase would continue for some time, and also that by 1945 the yield would be doubled. This prediction appears to be reasonable in view of the fact that the United States now produces only a small percentage of the filberts it consumes annually, and because of the suitability of the soil and climate of the region west of the Cascade Mountains for the profitable production of that nut.

Since the introduction of the filbert from Europe and Asia Minor, about a dozen insects indigenous to the Northwest have been reported as attacking it, but, with the exception of *Melissopus latiferreanus*, none has yet developed to a point where serious losses are occasioned by its activities. It is reasonable to expect, however, that with the expansion of the areas devoted to filbert growing, and also as the present young plantings develop with the years, some of the insects now attacking it will increase in importance and gradually assume the role of pests. Undoubtedly other insects also will find in it a suitable host. This has been true of many an introduced plant.

COMMON NAME, DISTRIBUTION, AND HOSTS.—*Melissopus latiferreanus* has been known as the Catalina cherry moth because it was originally described by Lord Walsingham (1879) from specimens infesting the fruit of a wild bush, *Prunus lyonii* Sargent, called the Catalina cherry. Because of its economic importance as a pest of filbert, however, the common name filbert worm is used in this paper.

According to unpublished records of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, the insect is generally distributed throughout the United States from the Atlantic to the Pacific. During the last 2 years detailed observations on the distribution of the insect have been made along the West Coast from the Canadian border to within 100 miles of the Mexican boundary. Thousands of specimens of likely host materials were collected to obtain definite evidence of distribution and positive records of hosts. The results to date show it to be generally found along the entire coast west of the Cascade and Sierra Nevada Ranges.

In the states of Oregon and Washington it has been reared from the galls and acorns of the Garry oak, *Quercus garryana*, the wild hazelnuts, *Corylus americana* and *C. cornuta*, and filbert, *Corylus avellana*. One adult of the species was bred from a walnut, *Juglans* sp. collected in the Willamette Valley in northwestern Oregon. Numerous specimens have been recovered from wild hazelnuts, oak acorns and galls, and Catalina cherries collected in California. For many years the Bureau of Entomology and Plant Quarantine of the California State Department of Agriculture has received specimens for specific determination from points throughout that state. Their records contain all those already mentioned and also the following from which *M. latiferreanus* was reared: Apricot, *Prunus* sp., chestnut, *Castanea* sp., chinquapin, *Castanopsis* sp., horsechestnut, *Hippocastanum* sp., orange and tangerine, *Citrus* sp., and peach, *Amygdalus* sp. The Division of Insect Identification of the U. S. Bureau of Entomology and Plant Quarantine has records of the insect being reared from beechnut, *Fagus* sp. Such a list would seem to indicate that the filbert moth is not fastidious as to hosts, and further investigations are likely to produce additional ones.

REARING FOR IDENTIFICATION.—One of the first objectives of the work was the definite specific determination of the insect being investigated. It was important to know whether only one species was in-

volved or two or more species were present to complicate the problem. The large and diverse collections of host materials made to define the distribution of the insect were particularly helpful for this purpose because they were made at various altitudes over a considerable area. Adult specimens emerging from them were submitted to the specialists of the Division of Insect Identification of the Bureau of Entomology and Plant Quarantine, who determined them as *Melissopus latiferreanus* (Walsingham).

The species is subject to extreme variation in color, size, and even in certain structures, and has been separated by Heinrich (1926) into seven varieties which have been designated by letters A to G. Three of these varieties are found west of the Rocky Mountains and four from the Rockies east to the Atlantic Coast. One of the latter varieties is also recorded from Mexico. Only varieties A and C have been reared at the Eugene laboratory to date, variety A from hazelnuts, and oak galls and acorns, and variety C from filbert nuts, Catalina cherry, hazelnuts, and oak acorns.

VARIETAL SUSCEPTIBILITY OF FILBERTS.—In addition to the filbert varieties originally imported into the Northwest, many new varieties have been developed from them subsequently by nut growers and plant breeders. Of the more than 500 varieties of filberts developed there are said to be 100 named ones, 12 or 15 of which are considered of economic importance. Since varieties of filberts are as distinct as varieties of tree fruits, and each possesses its peculiar characteristics, it is not unlikely that some may be more resistant than others to the attacks of the filbert worm. It is the intention to study as many of the varieties as feasible to ascertain the degree of susceptibility of each. Studies have already been initiated with 23 vaireties, including all those now commercially grown in the Northwest. Early results show a trend toward marked variation in susceptibility for the group as a whole, but to a lesser degree for the more common varieties.

INFESTATION IN PREMATURE DROPS AND HARVESTED NUTS.—During August and early in September when filberts are maturing many nuts drop prematurely because of inadequate pollination, on account of being diseased or infested by worms, or from other causes. Studies were undertaken to determine the extent to which nuts infested with worms dropped from the trees and to get the relation of these fallen ones to the infestation records of filbert nuts at harvest time. The results of one season's observations may not give a true indication of conditions, nevertheless they appear significant. During one season 60.3 per cent of the total infestation of the entire crop on 158 trees in Lane County, Oregon, orchards was in the premature drops, while 39.7 per cent was in the harvested nuts.

LIFE HISTORY AND HABITS.—The investigations cover a period of only 2 years, hence only brief mention will be made here of the salient features in the life history of the filbert worm as studied under laboratory and insectary conditions at Eugene, Oregon.

The eggs, deposited singly on or near the filbert nuts, hatch in 8 to 11 days; and the larvae develop rapidly after entering the nut and are ready for hibernation in about 3 weeks, when many of them leave the host. They overwinter as larvae in cocoons formed in trash or rolled leaves under the trees or on the surface of the ground, in the host fruits, or under other conditions of shelter. Some hibernate within the surface soil, their cocoons being covered with particles of soil. Pupation takes place the following season from early May to late August. The duration of the pupal stage depends upon the prevailing temperatures, in 1939 averaging about 33 days for individuals entering this stage in June and only 15 days during the early part of August.

Adults have emerged in the laboratory from material from various hosts from late in May to early in October. The period of maximum emergence of adults from the overwintering larvae depends on the host in which the hibernating form had developed the preceding season. Emergence seems to be synchronous with the formation and development of the host fruit. For example, most of the wild hazelnuts develop during June, and *Melissopus* adults from larvae reared from wild hazel emerged chiefly during that month. Adult moths from filbert material emerged during July and the early part of August, their emergence synchronizing with the

formation and development of that nut. On the other hand, since oak acorns do not develop until August, larvae which had fed on oak acorns the preceding season transformed into pupae later than any others studied and did not produce adults in any large numbers until August, when the new crop of acorns was in the process of formation and development.

The moth has rarely been observed in flight. Often moths do not take to flight even when pushed or shoved about in laboratory cages. In larger outdoor cages, however, they have been seen to dart about or to fly short distances.

Mating of adults in laboratory cages has been observed only when the temperature was 64 degrees F. or slightly higher, and only at dusk or when it was moderately dark as at dusk.

The filbert worm has one generation a year in Washington and Oregon with a tendency toward a partial second brood. In the Sacramento Valley of California the moth is found in the field as early as April. This early seasonal appearance of the moth coupled with the tendency of the species towards a partial second brood farther north may be indicative of at least a possible full second generation in the valleys in the southern half of California.

ORCHARD DISTRIBUTION OF THE WORM POPULATION.—During the initial surveys of infested filbert orchards in 1937 several growers mentioned an unusual concentration of worm activity in certain restricted parts of their orchards while other portions of the same groves produced only sound nuts. A detailed study of this tendency towards a localization of infestations within orchards was undertaken because the information thus obtained would be useful in the planning and later in the interpretation of the results in the study of methods of control. The indicated trends appear to show (1) that irrespective of the intensity of infestation in a filbert orchard wide variations occurred in the number of wormy nuts produced by individual trees, (2) that there appeared to be more uniform infestation where fewer varieties were planted in an orchard, (3) that in the more heavily infested orchard there seemed to be a greater range of extremes in the numbers of infested nuts, and (4) that the most neglected orchard harbored the largest percentage of worms. Close study of the details of this experiment shows that it would be unsafe to assume that a uniform infestation exists in any orchard.

PARASITES.—Under the existing light infestations it was not expected that many natural enemies of the filbert worm would be encountered in the short time the insect has been studied. However, six parasites of the larva, two of which are species new to science, have been reared in comparatively large numbers at the Eugene laboratory and determined by the specialists of the Bureau of Entomology and Plant Quarantine. These species will now be discussed briefly.

The following rearings of *Calliephialtes nucicola* Cush.[2] have been made: From infested oak galls, 42 from Eugene and North Albany, Ore., 5 from Santa Margarita, Ojai, and Gasquet, Calif., 1 from acorns collected at Woodburn, Ore., and 1 from Catalina cherries collected at Santa Barbara, Calif.

Seven adults of the chalcid *Elachertus evetriae* Girault[3] emerged from a *Melissopus* larva infesting a filbert nut collected in Eugene, Ore.

Thirty-eight adults of *Lissonota* sp.[2] were reared as follows: 6 from isolated *Melissopus* larvae infesting oak acorns in Oregon, 4 from isolated larvae from Catalina cherry from Santa Barbara, Calif., 5 from Oregon filbert nuts, 14 from oak acorns collected in Oregon, and 9 adults from Catalina cherry from Santa Barbara, Calif.

In all, 19 specimens of *Macrocentrus ancylivorus* Roh, have been reared from acorns from Eugene, North Albany, Monmouth, Dilley, Newberg, and Tygh Valley, Ore. Four of these were reared from isolated *Melissopus* larvae. C. F. W. Muesebeck, who identified the specimens, makes the following statement: "I have spent considerable time comparing these specimens with typical *ancylivorus* and have found no structural basis for distinguishing them. I believe them to be *ancylivorus*. . . . "

Eighteen individuals of *Phanerotoma tibialis* (Hald.)[4] were reared during 1939 from infested acorns collected at Eugene, North Albany, Dilley, Monmouth, and

[2] Determined by R. A. Cushman.
[3] Determined by A. B. Gahan.
[4] Determined by C. F. W. Muesebeck.

Woodburn, Oreg. One of them emerged from an isolated *Melissopus* larva.

Twelve adults of *Bassus nucicola* Mues. were reared from as many *Melissopus* larvae isolated in individual glass vials. Also 160 specimens have been reared from infested oak galls from various California localities, including Sacramento, Shandon, Applegate, Sonoma, San Lucas, Santa Margarita, and Visalia. Five specimens have been reared from infested acorns from Monmouth and Woodburn, Ore., and Tampico, Wash.

A single specimen of *Phorocera* sp. was reared from a *Melissopus* pupa collected as a larva infesting a filbert nut in Springfield, Ore. The determination was made by D. G. Hall, who reported, "This specimen runs to *Phorocera erecta* Coq. in Aldrich & Webber (1924) and agrees fairly well with the description and type. But this species has never been recovered from the host indicated." Hall hesitated to determine the single specimen submitted as that particular species.

A species of such wide distribution and diverse kinds of hosts as the filbert worm must be subject to the attacks of additional parasites. In fact, several other species have been reared in very small numbers from plant-host material infested chiefly by *Melissopus*. Further rearing will undoubtedly permit the definite association of many of these parasites with that insect host. As the work is continued the list of parasites will undoubtedly increase still further, more appearing especially from localities where heavier infestations over a large area may occur. Today concentrated infestations are to be found only in small spots in the filbert-growing sections of the Northwest.

SUMMARY.—The profitable growing of filberts in the Pacific Northwest, a new industry in the United States, is threatened by *Melissopus latiferreanus*, called in this paper the filbert worm. This insect is widely distributed and attacks a number of diverse host plants, although the most important economic damage is done by the larvae feeding in the kernel of the filbert nuts. In addition to the direct damage to the nuts, considerable expense is incurred in the sorting of infested nuts from the sound ones. Its wide range of distribution, the diversity of its hosts, and the rapidly increasing filbert acreage make it a pest of potential importance to the filbert industry in the Northwest. It attacks all varieties of the filbert that are of commercial importance, some to a lesser degree than others.

The life history and habits of this insect are briefly as follows: Eggs hatch 8–11 days after deposition, and in about 3 weeks the larvae are fully fed and ready for hibernation; they overwinter in cocoons until 2 to 5 weeks before emergence as adults, at which time they go into the pupal stage. In Washington and Oregon the insect has one full generation a year and a partial second. Natural control agencies discovered during 2 years of study include more than six hymenopterous parasites of the larva and one dipterous pupal parasite.—6-6-40.

LITERATURE CITED

Aldrich, J. M., and Webber, Ray T. 1924. The North American species of parasitic two-winged flies belonging to the genus Phorocera and allied genera. U. S. Natl. Mus. Proc. v. 63, Art. **17**: 77.

Heinrich, Carl. 1926. Revision of the North American Moths of the Subfamilies Laspeyresiinae and Olethreutinae. U. S. Natl. Mus. Bul. **132**: 66–9.

Muesebeck, C. F. W. 1940. Two new reared species of Bassus (Hymenoptera: Braconidae). Proc. Ent. Soc. Wash. v. **42**(4): 91–3.

Thompson, B. G. 1938. Progress report on the control of filbert insects. Twenty-fourth Annual Meeting of the Western Nut Growers Association, December 8–9, 1938, pp. 141–43. (Published with Thirtieth Annual Report, Fifty-third Annual Meeting, Oregon State Horticultural Society, Eugene, Ore., December 6-7-8, 1938.)

Walsingham, Lord. 1879. Illustrations of typical specimens of Lepidoptera Heterocera in the collection of the British Museum. Part IV. North American Tortricidae. Brit. Mus., London. See p. 70.

MEMORIAL MEETING FOR W. S. BLATCHLEY

The W. S. Blatchley Club, formerly the Hamilton County Nature Study Club, held a memorial meeting for the late Doctor Blatchley for whom the club was named. The meeting was held at Noblesville, Indiana, October 11, and the memorial tribute was given by J. J. Davis of Purdue University.

Barium Compounds as Poisons in Firebrat Baits[1]

CHARLES H. RICHARDSON and EDWIN J. SEIFERLE, *Iowa State College, Ames*[2]

During the course of an investigation of stomach poisons, it was found that barium carbonate possessed considerable toxicity to the firebrat, *Thermobia domestica* (Packard), when incorporated in a suitable bait mixture. Since barium carbonate is definitely lower in cost than the poisons currently recommended for firebrat baits except arsenic trioxide, and is safer than the latter poison for use in the home, it seemed advisable to examine it further. At the same time twenty-five other barium compounds were tested for toxicity to this insect. The experiments were made at Ames, Iowa, in the period from January 4 to August 15, 1938.

HISTORICAL.—As insecticides barium compounds are not new. The older European literature contains many references to barium chloride, which is reported to have both stomach-poison and contact-poison properties (Trappmann 1927). Barium fluosilicate has been tested on a large number of insect species, and has found some practical applications. Barium carbonate has also been tried by a number of workers with variable results (Lefroy & Finlow 1912–14; Moore & Campbell 1924; Marcovitch 1928; Peairs 1936). So far as tested, barium chromate, fluoride, oxalate, peroxide, stearate, sulfate and thiosulfate have shown no marked toxicity to insects (Lefroy & Finlow 1912–14; Jackson and Lefroy 1917; Moore & Campbell 1924; Richardson & Seiferle 1938).

The earliest reference to the use of a barium compound in a bait for firebrats or other lepismatids seems to be that in Spencer's unpublished thesis.[3] This author used barium carbonate at about 12 per cent of a flour-meat mixture, testing the bait on a single pair of firebrats; the insects died in 90 and 122 hours.

In Australia, a species of silverfish, *Ctenolepisma longicaudata* Escherich, has been controlled by baits containing barium fluosilicate (*Anon.* 1935; 1936a; 1936b; 1937; Lindsay 1938). Seiferle *et al.* (1938) have investigated baits containing barium fluosilicate for the firebrat. They found this compound less toxic than sodium fluoride and sodium fluosilicate, on the basis of median lethal time, but more toxic than sodium fluoaluminate (cryolite) when comparisons were made of median lethal times for equal concentrations of poison. In their paper most of the literature pertaining to poisons tested in firebrat baits is cited.

Barium compounds are definitely toxic to vertebrate animals. McNally (1937) cites instances of recoveries of man from doses as large as 35 grams, and deaths from doses as small as 10 to 12 grams. He states that fatal poisoning of humans by barium salts is comparatively rare. Schwartze (1920) found that barium carbonate was two-thirds as active as barium chloride to rats when fed by mouth. The chromate was practically nontoxic, and a barium soap (chiefly barium palmitate) was about equal in toxicity to barium carbonate for the same animal.

Since the action of barium carbonate on vertebrate animals is slow so that the chance of death from accidental or intended poisoning is smaller than that from many other poisons, this compound is generally regarded as one of the safer poisons for use in rat baits.

PLAN OF EXPERIMENTS.—In general, the baits, and method of administering them, were those employed by Seiferle, *et al.* (1938). A small quantity of bait was placed in a shell vial and a single firebrat was introduced. The bait consisted of rolled oats, sugar and sodium chloride, finely ground and mixed in the proportions, 200:10:5. A dye was added to the bait in the concentration of 0.5 per cent, and the poison, with a few exceptions, at 4 per cent concentration. Nearly all the barium compounds were of chemically pure, reagent grade; a few of lower grade were the best commercial products obtainable on the American market.

The dye, *Scarlet R*, a nontoxic bis-azo compound, was added to determine whether feeding on the baits had taken place. Insects that consumed relatively large quantities of a bait containing Scarlet R assumed a deep red color easily visi-

[1] Journal paper J-755 of the Entomology and Economic Zoology Section of the Iowa Agricultural Experiment Station, Ames, State project 137.

[2] The writers wish to acknowledge the efficient aid of Miss Jean Austin during this investigation.

[3] Life history and control measures of the silverfish, *Thermobia domestica* (Packard). Univ. of Illinois, Urbana, E. A. Spencer, 1924.

ble through the integument by means of a hand lens. On the other hand, insects that ate little showed at most a slight pink or pale reddish color. The presence of the dye was confirmed at the conclusion of the experiment by dropping the insect in chloroform which immediately intensifies the color. In this manner, the ingestion by

otherwise there were 5 replications. Examination of the experiments were made at 24, 48, 72 and 96 hours.

Controls were of three kinds: a standard poison bait to control mortality, made of the same kinds and proportions of materials as the experimental baits except that it contained 4 per cent sodium fluor-

Table 1.—Mortality of the firebrat from barium compounds in baits at 4 per cent concentrations Time 96 hours. Temperature 38°C.

Compound	Mortality Group	Actual Mortality†	Barium in Compd.	Sol. of Compd.‡	Sol. of Ba
		Per cent	Per cent	g. per l.	g. per l.
Barium bromide	0–2	0	41.2	1130.	522.0000
Barium chromate		0	54.0	0.0053	0.0029
Barium diphenylamine sulfonate		0	21.9	>2.	—
Barium diphosphate		0	58.8	0.05	0.029
Barium iodide		0	35.1	2300.	808.
Barium sulfate		0	58.8	0.0031	0.0018
Barium thiosulfate		2	51.3	0.5	0.26
Barium chloride		2	56.2	402.	265.
Barium nitrate		2	52.6	137.	72.
Barium oleate		2	19.6	Insol.	—
Barium chlorate	3–25	4	42.6	539.	243.
Barium perchlorate		4	40.8	3025.	1236.
Barium sulfide*		4	81.1	Decomp.	—
Barium formate		6	60.4	338.	204.
Barium acetate		8	50.2	768.	413.
Barium iodate		14	27.2	0.39	0.11
Barium oxide		22	89.6	69.	62.
Barium hydroxide	26–50	26	43.5	77.	62.
Barium tartrate		31	45.3	0.34	0.16
Barium fluoride*		35	78.3	1.62	1.28
Barium bromate		36	33.4	12.	4.
Barium triphosphate	51–75	51	68.4	Insol.	—
Barium peroxide		56	81.1	Insol.	—
Barium oxalate*		62	56.4	0.12	0.07
Barium carbonate	76–100	82	69.6	0.03	0.02
Barium fluosilicate*		91	49.2	0.41	0.21

* Repellent compound.
† Based on at least 5 subsamples of 10 insects.
‡ Solubility data from Comey & Hahn (1921), Merck (1930) and Seidell (1919).

the insect of more than traces of the bait could be positively detected. The selection of *Scarlet R* to detect feeding, and its use at the 0.5 per cent level, are the outcome of experiments with a considerable number of dye compounds. The results of these experiments will be published later.

In an experiment there were ten adult insects, each insect in its individual vial. The criterion of death was the inability of the insect to move when the antennae, legs or tarsi were pinched with forceps. If a compound proved appreciably toxic, the experiments were replicated 10 times;

ide; a standard food like the standard poison bait but without sodium fluoride; and a starvation control consisting only of a vial and a paper perch for the insect to rest upon. The purpose of the latter control was to serve as a check on the ability of the insects to survive the experimental period (96 hours) without feeding. Of the 790 insects starved for 96 hours, only 0.5 per cent died of all causes during this time.[4] All experiments were maintained

[4] Recent experiments show that the insects can apparently derive some nourishment from the paper (medium-weight typewriter bond) of which the perches were made. The paper perches were common to all experiments and controls.

at 38 degrees C. and a relative humidity of about 70 per cent.

RESULTS.—The results of the tests on the several compounds are presented in table 1. Comparison of the mortality data for each barium compound was made with that for the standard sodium fluoride bait, the chi-square test being used in all doubtful cases to determine significance. The comparisons were always made with data derived from experiments which extended over the same period of time. Mortalities at 96 hours only are given in the table. All compounds except barium carbonate and barium fluosilicate proved significantly different in mortality from sodium fluoride.

Similar comparisons were made to determine relative repellence, the percentage of insects colored by *Scarlet R* in the experimental baits at each of the 4 time levels being compared with the percentage colored in the standard food baits at the same time levels. The 4 compounds which proved to be repellent on the basis

Table 2.—Percentage mortality of firebrats on baits containing barium carbonate and sodium fluoride.

COMPOUND AND CONCENTRATION	PERCENTAGE* DEAD IN:			
	24 hrs.	48 hrs.	72 hrs.	96 hrs.
Barium carbonate 4%	27	55	75	82
Sodium fluoride 4	27	51	77	89
Barium carbonate 6%	27	66	78	89
Sodium fluoride 6	51	66	77	91
Barium carbonate 7%	24	59	79	93
Sodium fluoride 7	21	52	71	88
Barium carbonate 8%	43	75	91	96
Sodium fluoride 8	33	53	71	90

* Based upon 10 or more subsamples of 10 insects.

of this information are designated by a footnote in table 1.

The mortality from baits containing barium carbonate is compared in table 2 with that from sodium fluoride baits at 4, 6, 7 and 8 per cent poison concentrations.

In figure 1 are given the repellent values (rate of coloring with *Scarlet R*) for barium carbonate and sodium fluoride at the same 4 concentrations and the same times as in table 2. The rate of coloring on standard food (without poison) is also shown on this graph.

The sexes of the insects which died in the experiments were recorded and the sex ratios were examined for evidence of differential toxic effects of the compounds. The chi-square test was used to determine whether the observed ratios departed sig-

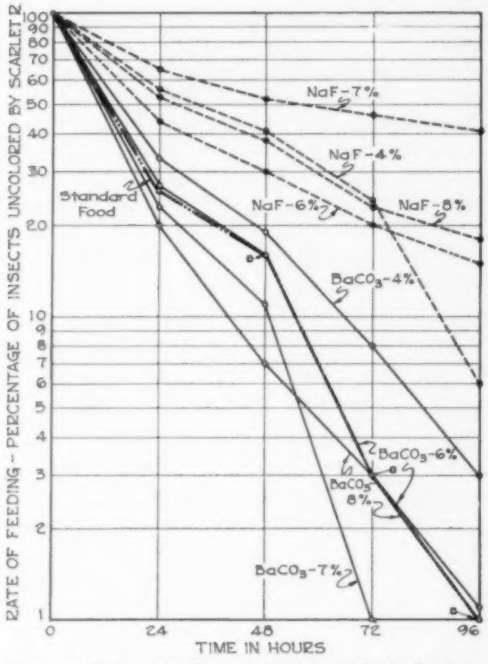


FIG. 1.—Rate of feeding on baits containing barium carbonate and sodium fluoride; and on unpoisoned food. The data are based on the percentage of firebrats which at each observation were not yet colored by *Scarlet R*. Each point on the curves represents information derived from at least 10 subsamples of 10 insects.

nificantly from the theoretical 50:50 ratio. The results are given in the discussion.

DISCUSSION.—Inspection of table 1 shows that no compound of high solubility in water at 38 degrees C. was markedly toxic, and that most of the appreciably toxic compounds were of relatively low solubility (62 grams of barium per liter or less). However, there are several compounds in the nontoxic group, notably barium sulfate and barium chromate, which are almost insoluble in water and probably insoluble in the digestive tract of the firebrat. Barium sulfide was so repellent that even if it were highly poisonous few of the insects consumed enough to obtain a lethal dose.

With reference to the more active compounds, the toxicity of barium peroxide is

probably associated with the oxidative activity as well as the barium content of the molecule. The toxicities of barium oxalate and barium fluosilicate are no doubt the result in part of the action of the respective acid radicals; and the higher mortality obtained from the latter compound is in accord with the greater toxic action of the hydrofluosilicic acid radical. So far as figures are available, barium carbonate is exceeded in insolubility in these compounds only by barium sulfate and barium chromate. The solubility increases considerably in the presence of carbonic acid, and the compound is readily decomposed by stronger acids. It seems highly probable, therefore, that barium ion is released readily from barium carbonate in the digestive tract of the firebrat. But the high mortality produced by this compound probably cannot be attributed entirely to the barium content, or to the ease with which barium ion is released in the digestive tract. Relative freedom from repellent properties is probably a factor of importance in its toxicity.

Only four of the compounds were significantly repellent, barium sulfide, as mentioned above, being most active in this respect. Barium oxalate bait was somewhat repellent up to 48 hours, but after that most of the insects fed on this bait. Barium fluosilicate and barium fluoride baits were repellent during the first 24 hours but not thereafter.

In this connection it should be stated that while *Scarlet R* will distinguish a readily-eaten from an avoided bait, it does not afford a quantitative measure of the bait consumed by the insects that have become definitely colored. Rather marked differences may, therefore, have existed in consumption of the various baits which imparted a definite red color to the insects.

No significant difference was found between the mortality from the barium carbonate and the sodium fluoride baits at 4 per cent poison concentrations (Table 2). At the 6 per cent concentrations, the performance of the baits was almost identical at all time levels except 24 hours. The higher mortality of sodium fluoride during this time interval was apparently anomalous. At 8 per cent concentration, significant differences between the two poisons were obtained at all time-levels except 96 hours when the mortalities became almost identical. Evidently barium carbonate and sodium fluoride produce the same or closely similar mortality when the firebrat is permitted to feed *ad libitum* on the baits.

The repellent effect of sodium fluoride was noticeable at all concentrations. Inspection of the curves in figure 1 shows that the rate of coloring by *Scarlet R* of the insects that fed on these baits was distinctly slower than the rate of coloring on the barium carbonate baits. Furthermore, the rate of coloring on the latter baits was similar to that on the unpoisoned standard bait. Apparently, within the range of the concentrations used barium carbonate has little effect on the rate of feeding while sodium fluoride slows up the feeding process. It is of interest to note that Schwartze (1920) found that the average intake by the rat of foods containing barium carbonate was approximately the same as that of unpoisoned foods.

At 96 hours, the mortality from sodium fluoride is about the same as that from barium carbonate. Yet, it is certain that baits containing the former compound are eaten less readily. Possibly sodium fluoride is more toxic to firebrats than barium carbonate on a dosage-weight basis; but Snipes *et al.* (1936) have stated that sodium fluoride has a contact action on this insect. The results of this investigation are concordant with this view, for it was noticed repeatedly that some of the insects died which had eaten mere traces, if any, of the poisoned bait.

The sex ratios of the insects that died in any series of tests, when the number was large enough, always agreed reasonably well with the theoretical 50:50 ratio. For example, barium peroxide bait killed 27 males and 42 females, barium oxalate bait 29 males and 33 females and barium fluoride bait 36 males and 55 females. Baits for which smaller numbers of insects were available furnished ratios which indicated agreement with theory. A closer agreement was found in the sexes of the 1,073 insects that died in the standard sodium fluoride baits, 49.6 per cent being males and 50.4 per cent females. The conclusion from these results is that within the concentration limits the barium compounds and sodium fluoride do not exert a pronounced selective toxic action on the sexes of the firebrat.

PRACTICAL APPLICATIONS.—In view of its marked toxicity, absence of repellent

properties, low toxicity to man and domestic animals and favorable cost, barium carbonate is recommended as the toxic ingredient of baits intended for use in dwellings, libraries, storehouses and other places infested with firebrats. The bait ingredients and their proportions by weight are as follows:

	Parts
Rolled oats, finely ground	86
Powdered sugar, confectioners'	5
Table salt, powdered	2
Barium carbonate	7

The ingredients should be thoroughly mixed in the dry condition to form a fine powder, without lumps. The same procedures and cautions observed in the use of the sodium fluoride bait (cf. Snipes *et al.* 1936) should be followed in the application of the barium carbonate bait.

SUMMARY.—Twenty-six barium compounds were tested for mortality to the firebrat, *Thermobia domestica*, in a food mixture at 4 per cent concentrations. The insects were allowed to feed *ad libitum* on the baits, observations for mortality being made at 24, 48, 72 and 96 hours. Seventeen of the compounds were nontoxic or produced mortalities in 96 hours of less than 25 per cent. The compounds of greatest solubility in water are in this group. Several of the compounds in this group whose solubilities in water are low probably owe their low toxicity to extreme insolubility in the digestive tract of the insect. Barium sulfide was so repellent that little of the bait containing it was eaten. Undetected differences in bait consumption may explain some of the observed differences in mortality.

The five most toxic compounds are placed in three groups on the basis of mortality in 96 hours: barium fluosilicate and barium carbonate followed by barium oxalate and then by barium peroxide and barium triphosphate. The difference between the last two groups may not be significant. At concentrations with 4 and 8 per cent barium carbonate produced approximately the same mortality as sodium fluoride; and it possessed little if any repellent effect while sodium fluoride rendered the bait noticeably repellent.

No significant sex differences in mortality were observed in these experiments.

A practical bait containing barium carbonate as the toxic ingredient is described.—6-7-40.

LITERATURE CITED

Anon. 1935. 9th Ann. Rept. Council Sci. Ind. Research. Australia.
Anon. 1936a. 10th Ann. Rept. Council Sci. Ind. Research, Australia.
Anon. 1936b. Jour. Council Sci. Ind. Research, Australia. **9**(4): 319–20.
Anon. 1937. 11th Ann. Rept. Council Sci. Ind. Research, Australia.
Comey, A. M. and D. A. Hahn. 1921. A dictionary of chemical solubilities, inorganic. 2d ed. enl. and rev. New York.
Jackson, A. D. and H. M. Lefroy. 1917. Some fly poisons for outdoor and hospital use. Bul. Ent. Res. **7**(4): 327–35.
Lefroy, H. M., and R. S. Finlow, 1912–14. Inquiry into the insecticidal action of some mineral and other compounds on caterpillars. Mem. Dept. Agric. India. Ent. Series **5**:269–327.
Lindsay, E. A. 1938. The silverfish. Published privately. A condensed version in Australian Women's World. April, 1938.
Marcovitch, S. 1928. Studies on toxicity of fluorine compounds. Tenn. Ag. Exp. Sta. Bul. **139.**
McNally, W. D. 1937. Toxicology. Chicago.
Merck's Index. 1930. 4th ed., Rahway, N. J.
Moore, W. and F. L. Campbell. 1924. Studies on non-arsenical stomach poison insecticides. Jour. Ag. Res. **28**(4): 395–402.
Peairs, L. M. 1936. Barium carbonate for the bean beetle. JOUR. ECON. ENT. **29**(3): 584–5.
Richardson, C. H. and E. J. Seiferle. 1938. Toxic and repellent properties of some inorganic and organic compounds and mixtures in grasshopper baits. Jour. Ag. Res. **57**(6): 423–32.
Schwartze, E. W. 1920. Toxicity of barium carbonate to rats. U. S. Dept. Ag. Bul. **915.**
Seidell, A. 1919. Solubilities of inorganic and organic compounds. 2d ed. New York.
Seiferle, E. J., J. A. Adams, C. M. Nagel and W. C. Ho. 1938. Effectiveness of fluorine compounds as food poisons for the firebrat. JOUR. ECON. ENT. **31**(1): 55–60.
Snipes, B. T., R. E. Hutchins and J. A. Adams. 1936. Effectiveness of sodium fluoride, arsenic trioxide and thiodiphenylamine as food poisons for the firebrat, *Thermobia domestica* (Packard). JOUR. ECON. ENT. **29**(2): 421–6.
Trappmann, W. 1927. Schädlingsbekämpfung. Grundlagen und Methoden in Pflanzenschutz. Leipzig.

Calcium Arsenate and Lead Arsenate Sprays with Soybean Flour for Codling Moth Control[1]

LEWIS T. GRAHAM and CHARLES H. RICHARDSON, *Iowa State College, Ames*

This is a report on an investigation initiated in 1934 to provide information on substitutes for lead arsenate in codling moth control. Major emphasis has been placed on commercial calcium arsenate because that arsenical seemed to offer considerable promise of effectiveness under Iowa conditions. Its residues contain no lead and they are easily removed; besides the price of calcium arsenate is somewhat lower than that of lead arsenate. Soybean flour was brought into the investigation as a sticker and spreader in 1937. This paper describes the results obtained in the season of 1939.

MATERIALS.—The calcium arsenate was a commercial material containing not less than 40 per cent arsenic (as As_2O_5) and not more than 0.75 per cent water soluble As_2O_5.[2] The lead arsenate was guaranteed to contain not less than 96 per cent of $PbHAsO_4$; and water-soluble As_2O_5 not more than 1.0 per cent. The ferrous sulfate was commercial $FeSO_4 \cdot 7H_2O$, and the soybean flour a widely-used commercial brand. The lime contained 97 per cent available calcium hydroxide.

EXPERIMENTAL DESIGN.—The experiment was made in a part of an 85-acre orchard at Mitchellville, Iowa during the summer of 1939. A randomized block design was used consisting of 4 blocks of 4 single row plots in each block. Since there were about 45 trees in each row, with the north half planted largely to the Jonathan variety, and the south half entirely to the Delicious variety, the data from each variety were analyzed separately. There were 6 count trees selected at random in each of the Jonathan and Delicious plots. The Jonathan rows contained trees 20 to 35 years old, and among them were some trees of different variety and size which caused this group to be heterogeneous. The Delicious trees were 23 years old and were fairly uniform with respect to size and crop.

The entire orchard was treated alike up to and including the calyx spray which consisted of lead arsenate 3 pounds and hydrated lime 5 pounds in 100 gallons of water. After that time, the following 4 treatments were applied to the experimental blocks: (1) calcium arsenate 3 pounds, ferrous sulfate 1 pound, soybean flour 12 ounces, hydrated lime 3 pounds, water 100 gallons; (2) lead arsenate 3 pounds, hydrated lime 3 pounds, water 100 gallons; (3) calcium arsenate 3 pounds, ferrous sulfate 1 pound, hydrated lime 3 pounds, water 100 gallons; (4) lead arsenate 3 pounds, soybean flour 12 ounces, hydrated lime 3 pounds, water 100 gallons. Fungicides were common to all treatments, and consisted either of dilute lime-sulfur or of dilute Bordeaux mixture. Four first brood cover sprays (up to July 1st), and 2 second brood cover sprays were applied to each plot, all sprays being timed by means of bait traps.

The apples on the count trees were examined three times during the season for codling moth injury. The first examination took place on June 30 at the end of the first brood; the second count on August 4, and the last count was completed on September 19 just before harvest. In the first two counts the apples were examined without removing them from the trees. Two hundred apples were inspected from each count tree, fruit from all sides and within the tree being included in the sample. At the preharvest examination, forty apples from each sample were cut open to determine the intensity of worm attack.

CRITERION OF EFFECT.—The criterion of codling moth injury used in this investigation was the number of apples damaged by the codling moth (stung and/or wormy fruit) per 100 apples.

In a separate investigation, to be reported elsewhere, it was found that another criterion, worms per 100 apples, gave a more sensitive test of the preharvest data but did not change the conclusions.

RESULTS.—The results are indicated in figure 1 and table 1, and the statistical analyses of the data from examination on

[1] Journal Paper No. J-756 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 389.

[2] This product was the ordinary calcium arsenate without added "safening" or "buffering" materials. It was not subjected during manufacture to special heat treatment nor to other special procedures in order to render it "safe" on foliage. The water-soluble As_2O_5 was determined by the A.O.A.C. method.

September 19 are presented in table 2. The observed differences with respect to treatment in the data obtained earlier (on June 30 and August 4) were not significant and the analysis is not given in this paper. By statistical analysis of the data of September 19, a significant difference is shown between treatments; and by comparison on the basis of single degrees of freedom, it is found that the variation arises from a difference in the insecticidal effectiveness of lead arsenate and calcium arsenate. The presence or absence of soybean flour did not appear to affect the toxic action of these sprays.

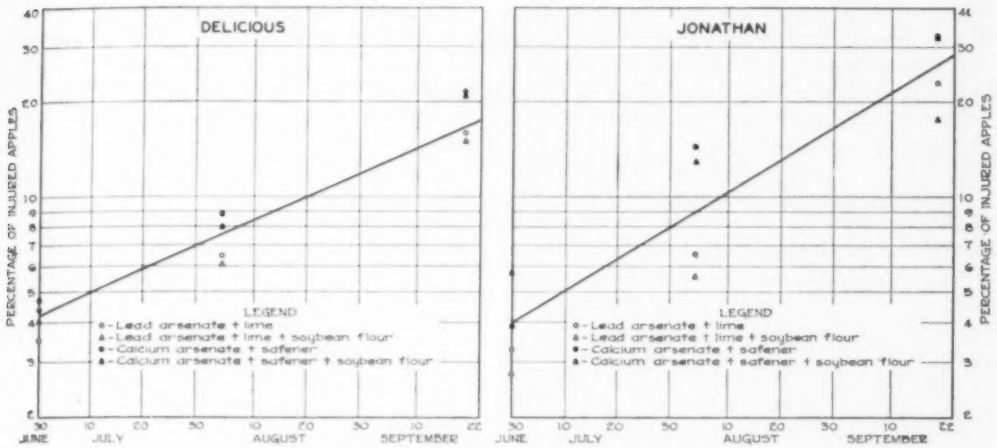


FIG. 1.—Rate of infestation of applies in experimental plots by the codling moth. Each point on the graphs is a mean based on 24 subsamples of 200 apples.

DISCUSSION.—Since 1933, a considerable number of field investigations of commercial calcium arsenate for codling moth control have been reported. Studies made in New York (Chapman *et al.* 1934), and New Jersey (Driggers 1937) emphasize the greater efficiency of lead arsenate as compared with calcium arsenate. On the other hand, the investigations of Garman (1933) in Connecticut, of Marshall (1935) and Marshall & Groves (1936) in Washington, of Sherman (1936) in Michigan, Vinson (1936) in Missouri and of Cutright (1938) in Ohio have, in general, placed calcium arsenate in a somewhat more favorable position relative to lead arsenate. For example, Marshall & Groves state that calcium arsenate compares favorably with lead arsenate but that maintenance of a suitable spray deposit is more difficult with the former compound. Sherman found calcium arsenate effective in light and moderate infestations but ineffective in severe infestations; and Cutright reported that calcium arsenate was 80 to 90 per cent as efficient as lead arsenate.

In an attempt to find a substitute for lead arsenate suitable under Iowa conditions experiments were begun with calcium arsenate in 1934 at Mitchellville. The results of this investigation obtained from a latin-square experimental design, failed to show a significant difference between

Table 1.—Comparison of lead arsenate and calcium arsenate for controlling the Codling Moth.

TREATMENT	PERCENTAGE OF DAMAGED FRUIT ON:		
	June 30	Aug. 4	Sept. 19
Delicious			
Lead arsenate+Lime	3.5	6.7	15.9
Lead arsenate+Lime +Soybean Flour	4.0	6.2	15.0
Calcium arsenate +Safener	4.7	8.8	21.7
Calcium arsenate +Safener+Soybean Flour	4.4	8.0	21.1
Jonathan			
Lead arsenate+Lime	3.3	6.6	23.2
Lead arsenate+Lime +Soybean Flour	2.8	5.6	17.6
Calcium arsenate +Safener	3.9	14.5	32.1
Calcium arsenate +Safener+Soybean Flour	5.8	13.2	32.2

the performance of calcium arsenate and that of lead arsenate (Hansberry & Richardson 1935). All the calcium arsenate sprays were buffered with ferrous sulfate. No clear indications of foliage or fruit injury were observed during this and subsequent seasons. In 1935, however, tests at Mitchellville and Des Moines gave less favorable results on codling moth for the calcium arsenate-ferrous sulfate mixture, but the design of the experiments was less efficient. In 1936 the calcium arsenate mixture was tested by growers in five orchards (Hansberry & Richardson 1936).

The codling moth infestation that year was light and the tests were not designed to give critical information. Nevertheless, except in one orchard, the calcium arsenate mixture gave a control about equal to that of lead arsenate. In 1937 experiments were made in two orchards (Richardson & Gunderson 1937); a severe hailstorm in July destroyed the fruit at Mitchellville but by the middle of that month no difference was observed between the efficiency of the calcium arsenate mixture and lead arsenate. In the other orchard, the percentage of wormy fruit at harvest was less than 10 in all plots and there were no significant differences. In 1938 the calcium arsenate mixture was again compared with lead arsenate in a small experiment at Mitchellville (Richardson & Gunderson 1938). At the end of the first brood (July 6), there was no difference between these treatments although the level of infestation was about 45 per cent wormy fruit. Subsequent examinations up to harvest showed a superior control for lead arsenate. The infestation during the season was one of the heaviest observed in this orchard.

The experiments performed in 1939 indicate clearly that while a difference existed between calcium arsenate and lead arsenate on each of the 3 dates of examination, this difference did not become significant until some time after August 4, which was well within the second brood infestation. This result supports the information gained from previous years in showing that calcium arsenate may generally be relied upon to control the first brood codling moth in Iowa. For heavy first brood infestations and for moderate to heavy second brood infestations lead arsenate is somewhat more reliable than the calcium arsenate-ferrous sulfate mixture.

Soybean flour has been used as an adhesive and spreader for codling moth sprays by Harman (1937), Farrar & Flint (1938), Lamerson & Parker (1939) and others; and the investigators cited have used from 4 pounds to 4 ounces of this material per 100 gallons of arsenical spray. Of these investigators, apparently only Lamerson and Parker have reported direct comparisons of sprays with and with out soybean flour for codling moth control. They used the rather high concentration of 4 pounds of soybean flour per 100 gallons of spray, and reported for these sprays considerably better control of codling moth than for the arsenical sprays without soybean flour.

A number of growers in Iowa have been using soybean flour for several years in codling moth sprays. The concentration commonly used has been 12 ounces per 100 gallons of spray; and accordingly this proportion was adopted for investigation. Work upon soybean flour was first undertaken by the Iowa Agricultural Experiment Station in 1937; in 1938 further tests of soybean flour were made but no significant difference was obtained in the performance of lead arsenate sprays with and without 12 ounces per 100 gallons (Richardson & Gunderson 1938). The results of the 1939 tests derived from a considerably more critical experimental design, indicate that 12 ounces of soybean flour contributed nothing to the efficacy of either lead arsenate or of the calcium arsenate mixture for codling moth control.

In table 2, Jonathan plots, a highly significant difference was found in the experimental error (block-treatment interaction) which measures the failure of the treatments to give consistent results in each block. This difference is believed to have arisen from differences in variety and size of the trees in these blocks.

The time-course of infestation in both plots during 1939 (Fig. 1) formed a geometric progression. When the means of the data from all treatments are plotted on a semi-logarithmic graph, they are fitted closely by straight lines. Although there was less than 5 per cent of damaged fruit at the end of the first brood period, nevertheless two cover sprays in the second brood period did not prevent the

doubling of the degree of infestation by harvest.*

SUMMARY.—In Iowa, ordinary commercial calcium arsenate sprays with ferrous sulfate "safener" control the first brood codling moth about as well as lead arsenate sprays. For heavy first brood infestations and for moderate or heavy second brood infestations lead arsenate is more reliable than the calcium arsenate-ferrous sulfate mixture.

Calcium arsenate sprays safened with ferrous sulfate do not injure apple foliage under Iowa conditions.

Soybean flour added to calcium arsenate or to lead arsenate sprays in the proportion of 12 ounces per 100 gallons of spray neither increases nor lessens the efficiency of the arsenical for codling moth control.

* The writers wish to acknowledge the interest and assistance of Mr. Robert M. Clark in whose orchard the experiments were conducted.

The rate of increase of infestation by the codling moth in the experimental plots as based on the percentage of injured apples follows a geometric progression.—6-20-40.

Table 2.—Analysis of variance of Codling Moth injury to apple samples taken on September 19.

SOURCE OF VARIANCE	DEGREES OF FREEDOM	MEAN SQUARE	
		Delicious	Jonathan
Treatments	3	1,155.57*	4,936.29*
Lead arsenate vs. calcium arsenate	1	3,408.17†	13,277.51†
Soybean flour vs. no soybean flour	1	57.04	720.51
Block	3	147.24	8,791.29†
Experimental Error	9	194.95	941.48†
Sampling Error	80	176.09	188.22

* Significant difference (P = 0.05).
† Highly significant difference (P = 0.01).

LITERATURE CITED

Chapman, P. J., G. W. Pearce, R. W. Dean and O. H. Hammer. 1934. Some comparisons between calcium arsenate and lead arsenate as general insecticides for apple. JOUR. ECON. ENT. **27**(2): 421–31.

Cutright, C. R. 1938. Nonlead arsenicals in the Ohio spray program. Proc. Ohio State Hort. Soc. 71st Ann. Meeting, 1938: 44–8.

Driggers, B. F. 1937. Experiments with calcium arsenate to control codling moth. JOUR. ECON. ENT. **30**(2): 314–9.

Farrar, M. D. and W. P. Flint. 1938. Soybean flour as a spray material. JOUR. ECON. ENT. **31**(4): 482–5.

Garman, P. 1933. Report on results of tests with lead arsenate substitutes. Conn. Pomological Soc. Proc. 43rd Ann. Meeting 1933: 70–80.

Hansberry, T. R. and C. H. Richardson. 1935. A design for testing technique in codling moth spray experiments. Iowa State Coll. Jour. Sci. **10**(1): 27–35.

Hansberry, T. R. and C. H. Richardson. 1936. Codling moth investigations. Trans. Iowa Hort. Soc. **71**: 63–6.

Harman, S. W. 1937. Stickers and spreaders used in lead arsenate sprays for codling moth control. JOUR. ECON. ENT. **30**(3): 404–7.

Lamerson, P. G. and R. L. Parker. 1939. Lead arsenate combinations and nicotine combinations as control measures for the codling moth, 1938. JOUR. ECON. ENT. **32**(6): 828–32.

Marshall, J. 1935. The experimental application of calcium arsenate for codling moth control in an arid region. JOUR. ECON. ENT. **28**(6): 960–5.

Marshall, J. and K. Groves. 1936. Three-year study of calcium arsenate for codling moth control. JOUR. ECON. ENT. **29**(4): 658–69.

Richardson, C. H. and H. Gunderson. 1937. The 1937 survey of orchard insect pests. Trans. Iowa Hort. Soc. **72**: 124–8.

Richardson, C. H. and H. Gunderson. 1938. Orchard insects of 1938. Trans. Iowa Hort. Soc. **73**: 139–47.

Sherman, F., III. 1936. Eight seasons' tests in codling moth control in Michigan. JOUR. ECON. ENT **29**(4): 653–5.

Vinson, C. G. 1936. Substitutes for lead arsenate in codling moth sprays. JOUR. ECON. ENT. **29**(4): 655–8.

The 1941 meeting of the Association has been definitely scheduled for December 29, 30 and 31, 1941, in San Francisco.

Trapping Honeybee-Gathered Pollen and Factors Affecting Yields.[1]

FRANK E. TODD, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine,* and ROY K. BISHOP, *Office of Agricultural Commissioner, Orange County, California*

The scale hive has long been used to obtain data on incoming nectar and honey production, but no method of measuring pollen income appears to have been worked out. Pollen is known to be essential to brood rearing, and information as to the quantity of incoming pollen would aid in determining management programs.

The relation of pollen income and reserves to the growth and reproduction of colonies has been studied by various investigators. Parker (1926) has noted that brood rearing is normally limited to that portion of the year when pollen is available in the field. Nolan (1925) has found that either incoming pollen or nectar stimulates brood rearing. Farrar (1936) has shown that an abundant fall pollen reserve promotes brood rearing during the winter and results in very populous early-spring colonies.

Alphonsus (1933) determined that on an average 144.9 milligrams of pollen was used in the production of one bee. Haydak (1935) found that 3.21 milligrams of nitrogen was used in the production of one bee. The nitrogen content of pollen varies widely, but the average value for pollens so far analyzed is 3.2 per cent. On this basis 100 milligrams of pollen would be required in the production of one bee. Nolan (1923) found that a very strong colony reared 202,830 bees in 1921 and 213,076 bees in 1922, or an average of about 208,000 bees per season. The pollen requirements for this number of bees would be 30.1 kilograms according to Alfonsus' estimate, and 20.8 kilograms on the basis of Haydak's figures. The quantity of pollen was used for purposes other than brood rearing is unknown. Weippl (1928) estimated the yearly pollen consumption of a strong colony at about 40 kilograms. These estimates indicate that large quantities of pollen are required to maintain a colony, but data appear to be lacking on the distribution of the pollen income during the year.

POLLEN TRAPS.—During the past year the seasonal distribution of the pollen income and the factors affecting this income were studied with the aid of pollen traps in four locations in California. This trap was a modification of one developed at the Intermountain Bee Culture Laboratory of the Bureau of Entomology and Plant Quarantine by Eckert (unpublished) to determine the plants on which bees were working, and later improved by Farrar (1934) to collect pollen for feeding. Their traps consisted of two parallel strips of metal, each having two rows of three-sixteenth-inch holes, mounted 2 inches apart. The trap was placed at the hive entrance so that an entering bee must pass through two holes, when the pollen load would be scraped from its legs and fall into a tray below. This trap retarded bee flight, and not enough ventilation was provided for use in a warm climate. The traps used by the writers in the pollen-income studies were of 5-mesh hardware cloth instead of sheet metal, and the strips were placed five-eighths inch apart so that the holes in the front strip were opposite the cross wire in the rear strip, to force the bees to make a turn in passing through. Such a trap provides sufficient ventilation, does not retard bee flight greatly, and removes the pellets efficiently.

EXPERIMENTAL PROCEDURE.—Traps were maintained in four beekeeping areas in California. One was located in the southern California lowlands at Orange, from February 1, 1938, to January 31, 1939; another was in the southern California mountains, in the Black Star Canyon, during the active season of 1938; a third was in the Sacramento Valley at Davis from June 16, 1938, to June 15, 1939; and the fourth was in the Sierra Nevada at Paynes Creek (3,000 feet) and Mineral (6,000 feet) from May 1 to October 15, 1938. The colony in this case was in the Sacramento Valley prior to May 1 and after October 15. The season opens in the latter area during early April; the record is therefore incomplete, lacking the month of April.

The pollen was for the most part col-

[1] A contribution from the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in cooperation with the University of California.

lected and weighed daily. At the same time records were made of weather conditions and other pertinent factors. Since the exposure to air in the trap during the day tended to dry the pollen, the weights given may be considered as on an air-dry basis; but owing to the variability of air humidity, some error is introduced by this method of handling.

The trap colony requires special attention, for it must also have pollen for maintenance. If no provision is made for pollen, brood rearing is curtailed and the colony becomes weakened or attempts supersedure. Small loads and bits of pollen not removed by the trap help colony maintenance, but this is insufficient to maintain colony strength. Combs containing pollen can be added to the colony at intervals, or the trap can be shifted from one colony to another.

RELIABILITY OF DATA.—The pollen collected in the traps does not represent the entire amount gathered by the colony, but it does comprise a substantial part of the harvest. Very small loads are not removed by the trap, and bits of pollen may remain on a bee after it has passed through the trap. On certain blossoms bees become coated with pollen, and this pollen is not brushed off or packed in the corbiculae, but the bees enter the hive and are cleaned up before returning to the field. Some nectars contain a considerable number of pollen grains. In the honey stomach much of this pollen is removed through the action of the proventriculus (Whitcomb & Wilson, 1929). Effort was made to keep traps only on relatively strong colonies, but it was usually impractical to keep a trap on the same colony throughout the year.

POLLEN YIELDS.—The quantities of incoming pollen during semimonthly periods throughout the year, in four localities, are shown in table 1. These data reduced to the average number of grams per day are presented graphically in figure 1.

Each area appears to have a distinct pollen curve. Where traps have been maintained for two years in the same locality, the season trends have been similar, with slight variations due to weather conditions and fluctuations in blooming of flora valuable as pollen sources.

In the southern California lowlands pollen came in throughout the year, but mostly between May and September. From December to February the source was mainly eucalyptus. The yield late in December was curtailed by a long rainy

Table 1.—Pollen yields during semimonthly periods in traps maintained in four beekeeping areas in California, 1938–39.

PERIOD*	GRAMS OF POLLEN TAKEN			
	Southern California		Sacramento Valley	Sierra Nevada†
	lowlands	mountains		
January				
1–15	93	—	0	—
16–31	139	—	Trace	—
February				
1–15	79	32	13	—
16–28	112	291	735	—
March				
1–15	425	270	1,630	—
16–31	243	389	2,889	—
April				
1–15	71	700	2,957	—
16–30	180	1,181	2,168	—
May				
1–15	743	575	984	2,354
16–31	1,181	753	582	627
June				
1–15	1,043	2,035	165	1,075
16–30	980	2,518	316	744
July				
1–15	1,615	2,585	570	1,074
16–31	2,493	1,486	1,293	832
August				
1–15	1,780	300	845	312
16–31	1,388	122	832	348
September				
1–15	624	125	804	295
16–30	963	129	523	198
October				
1–15	445	90	345	218
16–31	201	59	218	—
November				
1–15	229	T	65	—
16–30	134	0	0	—
December				
1–15	375	0	0	—
16–31	8	0	0	—
Total	15,540	13,640	17,984	8,077

* All figures for January and the Sacramento Valley figures up to June 15 are for 1939; all others are for 1938.

† This colony was in Sacramento Valley before May 1 and after October 15, 1938.

spell. Mustard was the chief source from February to April, but the plowing under of this cover crop late in March curtailed the supply. Pollen from sources other than orange was meagre during the orange bloom in April, but olive and walnut became available in May. Miscellaneous, as yet undetermined, sources furnished pollen during the remainder of the year. Normally there is no cessation of brood rearing in this area.

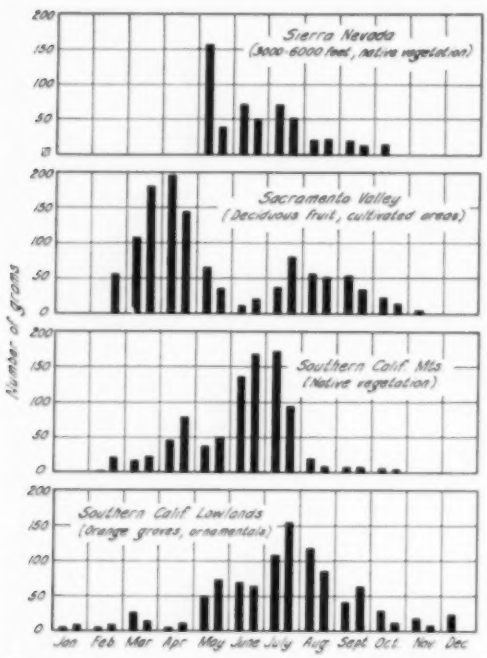


FIG. 1.—Average number of grams of pollen trapped per day during semimonthly periods.

The trap in the southern California mountains was located but 10 miles from the lowlands. The chief difference between the two areas was in the type of vegetation, rather than in temperature or other weather factors, although there was a little less fog in the mountains. The chart shows a pollenless period of some 90 days in the winter, when there was also a cessation of brood rearing. In contrast to the lowlands, this section had a greater pollen income in April than after August 1.

In the Sacramento Valley there were two distinct peaks of pollen income. The first rise, between February and May, was in rhythm with the blooming of deciduous fruits and the second rise with the blooming of the star thistle. During the low in the pollen cycle occurring late in May and in June, there was a comparative dearth of blossoms and brood rearing was greatly curtailed. Little pollen came in during a 75-day winter period, and there was an accompanying cessation of brood-rearing.

The Sierra Nevada record is incomplete because the trap was located in a commercial apiary that was moved in from the Sacramento Valley the first of May. The colonies reached the mountain location (3,000 feet) at the peak of spring pollen income. The season at this elevation opens early in April. The small quantity late in May was due to declining sources and bad weather, while the rise in June accompanied a second move to a higher elevation (6,000 feet), where springlike conditions were again encountered. There was then a gradual decline until the first of August, followed by moderate pollen income to the middle of October. Although killing frosts occurred late in September, pollen continued to come in until the weather was too cool for bee activity.

FACTORS AFFECTING POLLEN YIELDS.—Seasonal trends in the pollen cycle are in rhythm with the flowering of the main pollen sources of a locality. Peaks in the pollen cycle do not occur during peaks of colony population, but they are correlated with the blooming of good pollen sources. Low periods in the cycle occur during the winter dearth and other periods during the year when bloom in the field is meagre. Not all plants are of equal value as pollen sources. Certain excellent nectar plants—orange, alfalfa, vetch, lima bean, and fireweed—are of little or no value as pollen sources, and during the flowering periods of such plants pollen income declines except where other sources are available. On the other hand, some good nectar sources—sweetclover, star thistle, and sages—are also good pollen sources, during the blooming of which pollen income increases as indicated by the July–September period in the Sacramento Valley record.

Wide daily fluctuations in pollen yields also occur, which are due to the influence of weather factors on bee activity as well as on vegetation. Atmospheric conditions affect the dehiscence of anthers. The working day of the bees may be cut short by cold, rain, or cloudiness. The work of Lundie (1925) and Hambleton (1925) shows that bees do not fly freely at temperatures below 50 degrees F., during

rains, or under cloudy conditions. The influence of weather factors on pollen yields may be illustrated by a 12-day period during deciduous fruit bloom having some favorable days interspersed with others having unfavorable conditions of wind, rain, low temperature, and cloudiness (Table 2). On the one clear, warm, windless day (March 1) 310 grams of pollen was trapped. High yields were obtained on each day these conditions were approached. On days when there was a strong wind (Feb. 28) or the weather was cool and cloudy (March 6) or rainy (March 8 and 9) pollen yields were curtailed.

Table 2.—Relation of weather factors to pollen income in trap at Davis, Calif., 1939.

Date	Temperature Maximum, °F.	Possible Sunshine, Per Cent	Wind During Day	Rainfall During Day, Inches	Pollen Income, Grams
February					
27	62	83	Moderate	0	267
28	61	92	Strong	0	70
March					
1	63	100	Drift	0	310
2	60	57	Light	0	170
3	59	77	Moderate to strong	Trace	97
4	59	100	Drift	0	197
5	60	96	Light	0	103
6	56	2	Light	0.11	17
7	56	42	Drift	0.05	14
8	50	0	Moderate	0.93	0
9	49	2	Moderate	0.54	0
10	58	57	Moderate	0	59

Pollen yields may also be influenced by the internal conditions of a colony. Colonies in the same location but differing in bee force may bring in different amounts of pollen on the same day, as shown by data from two colonies in table 3. During the 10-day period the trend in pollen income was similar, but the yield of colony A was about one-third that of colony B. Colony A not only had a smaller field force, but the pollen income was more affected by adverse weather conditions, as indicated by the low pollen yields on overcast days with maximum temperatures of 62 and 67 degrees. Strong colonies have been observed to fly at lower temperatures than do weak colonies.

It is probable that demand for brood food and room for pollen storage may influence pollen-gathering activity. In fruit orchards, colonies with brood have been found to bring into the hive about twice as much pollen as package-bee colonies of equal bee force but without brood to feed. Pollen samples from colonies side by side may come from predominantly different sources, and colonies starved for pollen appear to be stimulated to maximum pollen-gathering activity when placed near supplies. During periods of pollen scarcity bees are reported to seek substitutes, such as bran, sawdust, and coal dust, which are of no known value for brood rearing.

Table 3.—Amounts of pollen trapped from two colonies of different strength, Orange, Calif., April 20–30, 1939.

Date	Temperature °F.	Weather Conditions	Pollen Income, Grams: Colony A*	Pollen Income, Grams: Colony B†
April				
20	51–78	Clear, low fog to 9 a.m.	34	112
21	51–78	Clear, low fog to 11 a.m.	43	68
22	53–62	Overcast	8	71
23	49–67	Overcast all day, light showers	9	130
24	44–69	Partly cloudy 10 a.m. to 1 p.m.	52	90
25	45–68	Partly cloudy all day	40	142
26	47–72	Clear in afternoon	68	184
27	48–75	Bright	97	217
28	52–77	Overcast to 10 a.m.	78	205
29	56–73	Overcast, low fog to 1 p.m.	45	171
30	50–76	Clear, low fog to 10 a.m.	42	186
Total			516	1,576

* Colony strength on April 30: Bee force 28,000, sealed brood 3,874 cells.

† Colony strength on April 30: Bee force 36,000, sealed brood 5,668 cells.

SUMMARY.—A study has been made of the seasonal distribution of pollen brought into the hive by honeybees. Pollen traps were prepared by placing two parallel strips of hardware cloth over the hive entrance in such a way as to permit the ready passage of field bees but to relieve them of their pollen loads.

Pollen trapped in four localities in California was weighed daily, and the average number of grams per day was calculated for semimonthly periods throughout the year. These data indicated the pollen cycles for the localities, which were found to be different for each locality and to have trends not unlike the brood-rearing cycles. The full year's trappings ranged from about 13.5 to 18 kilograms per colony for the various areas.

Pollen yields were found to be influenced by weather factors and by colony strength. Seasonal trends were in rhythm with the flowering of good sources. Peaks in the cycles occurred, not during population peaks, but during the blooming of good sources, while lows occurred during dearth of blossoms.—7-31-40.

LITERATURE CITED

Alfonsus, Erwin C. 1933. Zum Pollenverbrauch des Bienenvolkes. Arch. f. Bienenk. **14**(5): 220–3.
Farrar, C. L. 1934. Bees must have pollen. Gleanings Bee Cult. **62**(5): 276–8.
Farrar, C. L. 1936. Influence of pollen reserves on the surviving populations of over-wintered colonies. Amer. Bee Jour. **76**(9): 452–5.
Hambleton, James I. 1925. The effect of weather upon the changes in weight of a colony of bees during the honey flow. U. S. Dept. Agr. Bul. **1339**.
Haydak, M. H. 1935. Brood rearing by honeybees confined to a pure carbohydrate diet. JOUR. ECON. ENT. **28**(4): 657–60.
Lundie, A. E. 1925. The flight activities of the honeybee. U. S. Dept. Agr. Bul. **1328**.
Nolan, W. J. 1923. A two-year brood curve for a single colony of bees. JOUR. ECON. ENT. **16**(2): 117–24.
Nolan, W. J. 1925. The brood-rearing cycle of the honeybee. U. S. Dept. Agr. Bul. **1349**.
Parker, Ralph L. 1926. The collection and utilization of pollen by the honeybee. N. Y. (Cornell) Agr. Expt. Sta. Mem. **98**.
Weippl, Theodor. 1928. Futterverbrauch und Arbeitsleistung eines Bienenvolkes im Laufe eines Jahres. Arch. f. Bienenk. **9**(3): 70–9.
Whitcomb, Warren, Jr., and Wilson, H. F. 1929. Mechanics of digestion of pollen by the adult honey bee and the relation of undigested parts of dysentery of bees. Wis. Agr. Expt. Sta. Res. Bul. **92**.

Relative Humidity and Nectar Concentration in Fireweed*[1]

H. A. SCULLEN, *Oregon State College, Corvallis*

INTRODUCTION.—The influence of nectar concentration on the behavior of field bees has been studied extensively by Geo. H. Vansell, Associate Apiculturist, U. S. Department of Agriculture, and to a more limited extent by the author throughout Oregon. Through these studies it has been clearly established that bees show a decided preference for the more concentrated nectars when working in the field.

A wide variation in the nectar concentration of some species of honey plants has been observed. The studies reported on in this paper were carried on to determine the possible correlation between certain atmospheric conditions and nectar concentration. All concentration records were determined with the standard Abbe refractometer.

RESULTS OF FIREWEED STUDIES IN THE FIELD.—These studies include nectar concentration records secured from the content of the honey stomach taken from bees working on the flowers of fireweed. This method was necessary in view of the fact that it is impossible to collect sufficient nectar with a pipette from the blossom of fireweed to make a determination. A total of 470 determinations were made from bees working on fireweed during the summer of 1937, largely in the month of July. Most of the records were secured near the village of Pittsburg in Columbia county at

Table 1.—Fireweed Nectar Concentration at Certain Relative Humidities—1937.[2]

Rel. Humidity	No. Bees	Average Nectar Concentration	Rel. Humidity	No. Bees	Average Nectar Concentration
29	13	65.6	52	4	56.8
30	11	65.6	52.5	5	42.0
31	38	65.5	53	5	47.8
33.5	10	65.6	55	11	46.6
34.5	10	65.5	56	15	40.1
35	10	64.9	56.5	13	49.1
38	5	60.4	57	5	49.3
38.5	20	61.8	58.5	2	43.4
39	5	62.4	59.5	5	43.6
39.5	5	59.8	60	3	39.5
40	14	61.3	61	18	39.3
40.5	10	64.5	62	9	34.3
41	5	57.0	63	10	38.3
42	5	59.9	64	1	31.0
43	9	58.0	65	33	38.3
44	5	54.2	65.5	5	36.6
45	20	58.6	66	14	33.9
46	10	50.8	70	10	36.5
47	1	45.5	70.5	8	36.3
48	14	49.9	71	5	35.4
48.5	5	50.3	72	6	25.8
49	5	42.2	74	5	35.1
50	9	50.0	75	5	32.2
51	10	48.5	79	9	23.5
51.5	10	48.6	87	5	28.5

N—50
Degree of Freedom—48
Sample value of "r"—(−90.3)
Standard deviation of relative humidity (S_Y)—13.7
Standard deviation of nectar concentration (S_X)—11.9
± two standard deviations (10.6) includes 95 per cent of the cases which would normally occur.
Average relative humidity ($\bar{Y}$)—52.7
Average nectar concentration ($\bar{X}$)—47.9

* *Chamaeneron angustifolium L.* = *Epilobium angustifolium L.*

[1] Published as Technical Paper No. 340 with the approval of the Director, Oregon Agricultural Experiment Station. Contribution of the Department of Entomology.

[2] The author is indebted to Robert G. Rosenstiel, Department of Entomology, Oregon State College, for compiling the above statistics.

an elevation of 1,000 feet. Extensive records were also secured at the Bedford Point lookout station east of Estacada in Clackamas county (elevation 2,500 feet), at the Joe Marty ranch east of Silverton (elevation 2,600 feet), and at the divide on Wilson River highway (elevation 1,600 feet). A limited number of observations were made at various other points in Tillamook, Clatsop, Columbia and Washington counties.

These observations were made during a time when the weather was generally clear. In the early morning the vegetation was wet with dew and the relative humidity was high. As the day advanced the humidity dropped rapidly, reaching a minimum in the early afternoon. As a rule these fireweed concentration records were taken each half hour during most of the day. Humidity, temperature and evaporation records were secured likewise each half hour immediately preceding the taking of the concentration records.

The blossom of fireweed is of such a nature that the nectar glands are freely exposed to atmospheric conditions, and for that reason its nectar concentration would be expected to vary more with evaporation tension than would be the case for plants having the nectar glands in a more protected blossom structure.

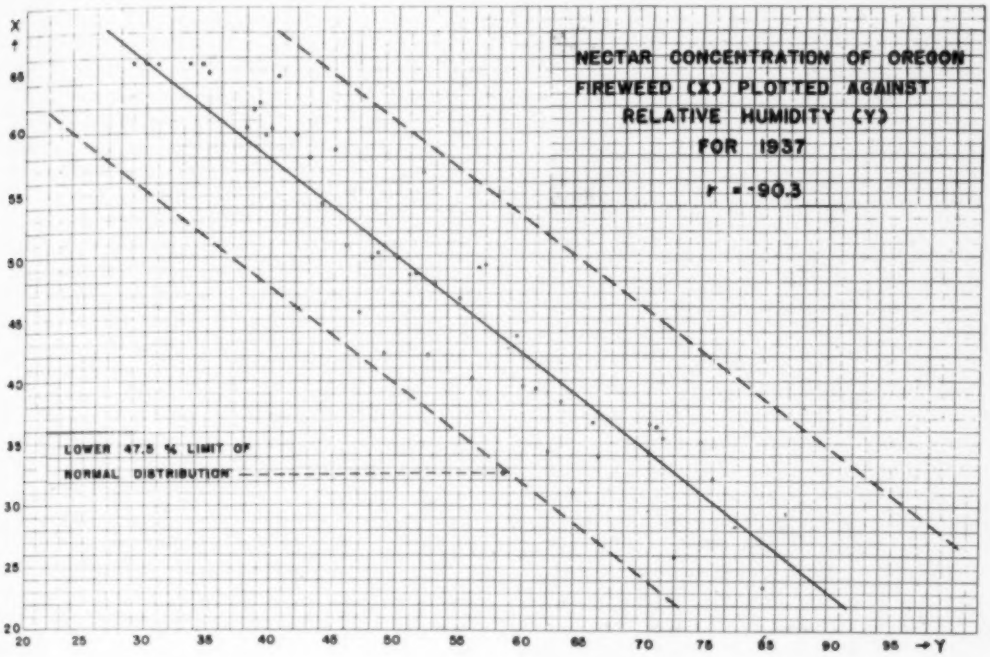


FIG. 1.—Nectar concentration of Oregon fireweed in relation to the relative humidity.

The readings from which figure 1 is secured are given in table 1.

The above data clearly shows that the relation of relative humidity to nectar concentration in fireweed is highly significant in a negative manner.—7-15-40.

COTTON STATES BRANCH CONVENTION DATES CHANGED

The dates of the 1941 convention of the Cotton States Branch have been changed to February 6, 7, and 8, 1941. The meetings will be held in Waco, Texas, in conjunction with the annual meetings of the Texas Entomological Society. The Raleigh Hotel has been selected for convention headquarters.

JOHN T. CREIGHTON, *Secretary–Treasurer*

CORRECTION

Mr. Philip C. Johnson requests that readers of the JOURNAL make the following change in the text of his article published in the October number:

Page 774, column 2, paragraph 5; the second sentence should read "In general this amounted to 12 per cent in those trees salvaged the same year they were attacked and 40 per cent in trees salvaged one year following attack."

The Toxicity of Tartar Emetic to the Honeybee[1]

J. E. Eckert, *Davis, California*

The beekeeping industry has been confronted for many years with ever increasing losses and with even the extermination of colonies in many areas as a result of the chemical warfare waged against insects. Scientific and trade literature contains many references showing that bees have been poisoned by the application of numerous materials in dust or liquid form, and when spread as poisoned baits. To review this literature would fill countless pages with examples of such losses to an industry that is primarily beneficial to agriculture through the work of the honeybee as an agent in the pollination of our food crops. Such a review could be justified only for the purpose of more forcefully bringing to the attention of all insect fighters that the welfare of beneficial insects should be given consideration in every insect control program along with the primary purpose of destroying the destructive forms. In most cases the time of application of poisons in relation to the blooming period is the deciding factor in determining the amount of injury that may be done to the pollinating insects. When poisons are applied to plants in bloom, great losses of bees may occur whereas the danger is generally reduced to the vanishing point when the applications of poisons affecting the honeybee are applied before or after the blooming period.

The honeybee is exposed to poisons through its need of collecting nectar and pollen for the maintenance of its colony. Poisons that fall into the nectar, whether in the liquid or solid form, are ingested and generally kill the workers before they can return to the hive. This results in a great reduction, or in the entire elimination of the field force gathering nectar. The pollen gatherers, however, can store poisoned pollen in their pollen baskets and transfer the poisoned pellets to their comb without being affected. This stored pollen then acts as a source of death to the house bees when they elaborate the pollen into brood food for the developing young. Again, field bees may be poisoned by the fumigating action of several dusts that adhere to the body hairs as they work among poison dust-covered blossoms. Another source of injury to bees is through the poisoning of their water supply by the scattering of poisoned bait and their sucking up of dew formed on poisoned plants. Poisoned baits in themselves are generally not attractive to the honeybee but if such baits (which generally contain some form of arsenic) fall in pools of water from which bees secure their water supply, the result is just as disastrous to the colony. A still more common source of injury to bees is the falling or drifting of poisons applied either on cover crops in bloom or blossoming plants in the vicinity of the crop treated (Eckert & Allinger, 1935).

The beekeeper is probably more cognizant of these facts than is the grower, the commercial pest control operator, or the research worker in the field of insect control. For this reason, the beekeeper considers every new insecticide or the promulgation of any new insect control program a possible source of danger to his livelihood until research or experience proves otherwise. This was the case this year in California when tartar emetic in a sugar solution was recommended for the control of the citrus thrips, *Scirtothrips citri* (Moult.).

Tartar Emetic Baits.—Tartar emetic (antimony potassium tartrate) has been used for a number of years in various forms of ant poisons but its use as a specific poison for certain forms of thrips is only of recent development. Richardson (1934) was among the first to determine that tartar emetic at 1 to 400 with 3 per cent molasses solution was very toxic to adult gladiolus thrips. Nelson (1938) and Bailey (1938) experimented with this poison in the control of the same thrips in 1937. Persing *et al.* (1940) carried on extensive field tests with the use of tartar emetic in a sugar solution in 1937, 1938, 1939 and 1940 in the control of the citrus thrips and found it more effective than all other control measures. Woglum (1940) first recommended its use to the members of the California Fruit Growers Exchange in April 1940.

For the control of the citrus thrips, the

[1] Contribution from the Division of Entomology and Parasitology, University of California, Davis.

recommendation was for the use of 1 to 1½ pounds of tartar emetic, 2 pounds of granulated sugar to 100 gallons of water, applied as a mist spray, using from 3 to 4 gallons of material to the average size tree at petal shedding time. Experimental data indicated that neither an increase in the amount of tartar emetic nor in the sugar had any significant difference in the effectiveness of the spray over a period of 40 to 65 days. The results on the test plots were so striking in 1937, 1938 and 1939 (Boyce & Persing 1939) on both lemons and oranges that the citrus growers accepted the recommendation without any reservations and made preparation to spray several thousand acres of oranges, lemons and grapefruit during the 1940 season. Tartar emetic was also applied as a liquid spray to some deciduous fruit trees and in dust form to onions, pears, beans and citrus on an experimental scale by Bailey and others.

Some growers apparently reasoned that if 1 or 1½ pounds of tartar emetic gave good control, 2, 4 or more pounds would be better and increased the sugar content in proportion to the amount of poison added. Occasional commercial operators adapted their equipment to apply a concentrated solution, using 30 pounds of tartar emetic, 60 pounds of sugar to 200 gallons of water, in the form of an atomized spray, applying only about 10 gallons of the material per acre. Many acres of citrus were sprayed during full bloom or earlier than experimental evidence indicated would be the most effective period for the control of the citrus thrips. In the case of lemons, which have an extended blooming period, the application of the tartar emetic spray during the blooming period cannot be avoided.

The concern of the beekeepers in this new insect control program was caused by their experiences in the past with arsenicals and other stomach poisons, their ignorance as to the effect of tartar emetic on bees as well as the fear of having hundreds of tons of orange honey ruined by the application of the spray material during the blooming period. Some were concerned by the thought that the sugar solution carrying the tartar emetic would be attractive to the honeybees either in its dilute form or after it had been concentrated by evaporation. Since several thousand colonies were involved, we were importuned from many sources to determine the probable effect on the beekeeping industry of the recommended spray schedule for the control of the citrus thrips.

METHODS AND MATERIALS.—Various methods were tried of feeding bees known quantites of sugar sirup, as used by other investigators (Hoskins & Harrison 1934), but the following procedure was adopted because of its simplicity and ease of opera-

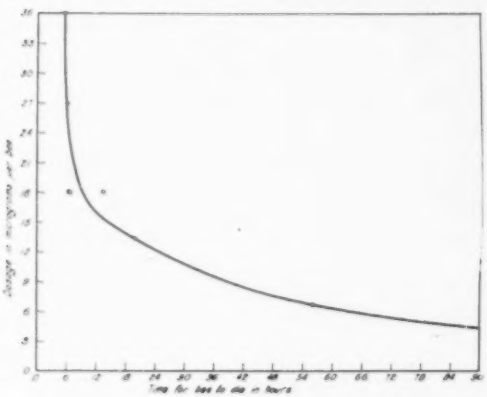


FIG. 1.—Relation of dosage to time elapsed before death of bees.

tion: Serological pipettes, holding 0.2 cc. and graduated to 0.001 cc. were used to feed hungry bees placed individually in queen mailing cages. (These are inexpensive two- or three-holed wooden blocks covered with a wire screen and sold by bee supply houses.) A battery of the pipettes was arranged in a holder so that several bees could be fed at the same time by placing the cages against the ends of the pipettes. By inclining the pipettes at about a 20 degree angle from the vertical, capillarity held the sirup in the pipettes without permitting any drops to accumulate at their tips. Individual feeding was resorted to when solutions were unattractive to the bees but in all cases the bees were fed through the wire of the small cages.

Bees were caught in a cage at the entrance of a hive by reducing the entrance of the hive to equal that of the cage. The cage was soon filled with the required number of fees which were then transferred to the individual cages after being released on a window in the laboratory. The bees were fed within one-half hour or

as soon as they manifested hunger. They were given access to sugar sirup after they received the poisoned sirup and were observed at intervals for results of the feeding.

Preliminary tests indicated that a solution of 0.12 grams of tartar emetic in 100 cc. of 20 per cent sugar solution was quite toxic to bees. This concentration is comparable to that of the poison contained in a formula of 1 pound of tartar emetic to 100 gallons of water. The additional sugar was added to make the solution attractive to the caged bees. Solutions were then made to contain 0.12, 0.09, 0.06, 0.045, 0.0225 and 0.0112 grams tartar emetic in 100 cc. of 20 per cent sugar sirup. The average capacity of the honey stomachs of hungry bees was determined as 0.039 cc. so it was decided to feed the bees 0.03 cc. of 20 per cent sugar solution containing the dissolved poison. Each concentration was fed to at least 20 bees and in case of the lower dilutions, where death resulted at fairly wide intervals, the test was repeated. Bees from the same colony were used throughout.

RESULTS.—The data indicate that the minimum lethal amount of tartar emetic was between 3 and 6 micrograms per bee and that death resulted over progressively longer periods as the concentrations were decreased. At the weaker dilutions, the symptoms of poisoning were not so definite as at the higher concentrations. (Fig. 1.)

DISCUSSION.—In recording the behavior of the bees, we had the same difficulty as other investigators have had in determining the exact time a bee could be declared dead. At best we concluded such records could vary from several minutes to even hours in the opinion of different observers. Consequently, the data were recorded to show the first visible effect of physical distress, when the bees' movements were restricted and uncoordinated, when they were permanently down and finally when they exhibited no reflex movements and could be declared dead. For all practical purposes, as well as for comparing the relative toxicity of different poisons, the bee can be declared fatally injured when its movements are so restricted as to cause it to remain in an unnatural position by a lack of coordinated movements. Bees seldom recover the power of locomotion when so stricken from ingested materials. In fact, unconfined bees will generally leave their hive when they first feel the effects of poisoning and will perish within a few hours outside the hive through the combined effects of poisoning, hunger, dust, etc. This behavior on the part of the bee is an important factor in keeping honey uncontaminated by poisons even when the colonies themselves may be killed.

The bees became quite restless soon after ingesting the higher concentrations of poisoned sirup and manifested their distress by moving rapidly and by frequently stroking the abdomen and mouth parts. With the stronger concentrations, the bees were observed to tumble in from one to two hours after taking the poison and to have their movements restricted shortly thereafter.

All bees in two observation hives died within three days while feeding on sugar sirup containing 0.12 grams of tartar emetic per 100 cc. of solution. The queen was the last bee to die in one of the hives.

The results of our preliminary investigations caused us to advise the beekeepers and growers that tartar emetic was toxic to the honeybee in quantities considerably under the concentrations recommended in the spray material and that it would be advisable for the beekeepers to become familiar with the spray program in their locations and to move their bees if the material proved injurious. We expressed the opinion, however, that since the bees were not attracted to such a dilute sugar solution, and since the material was to be spread so thinly over each tree, that there would be little damage if the spray was applied in the concentrations recommended and after a majority of the petals had fallen from the orange trees.

Personal interviews with beekeepers whose apiaries were located in the vicinities sprayed with the tartar emetic-sugar solution revealed no authentic losses of bees from this source. One citrus grower and beekeeper reported no noticeable loss of bees in his colonies located adjacent to an orange grove sprayed with the tartar emetic solution while the trees were in bloom. The lack of complaints of losses from beekeepers to the county commissioners can be taken as an indication that little, if any, harm resulted this year to bees from the application of the tartar

emetic sugar solution in the control of the citrus thrips.

The application of tartar emetic in dust form to citrus or deciduous fruit trees, while not justified as a control for thrips from present experimental results, might prove more destructive especially if the material is permitted to drift to pollen plants in adjacent fields or to cover crops within the fields treated. In such cases the bees will carry the poisonous material back to their hives with pollen and, judging from past experiences, the poison will prove injurious to the brood and house bees.

CONCLUSIONS.—While the minimum lethal dose of tartar emetic was found to be between 3 and 6 micrograms per bee, the tartar emetic-sugar spray applied in greater concentrations in the control of the citrus thrips in California, did not cause noticeable loss this year to colonies in the vicinity of treated fields.—7-15-40.

LITERATURE CITED

Bailey, S. F. 1938. Thrips of economic importance in California. Univ. of Calif. Agr. Exp. Sta. Circ. **346**, p. 56.

Boyce, A. M. and C. O. Persing. 1939. Tartar emetic in the control of citrus thrips on lemons. JOUR. ECON. ENT. **32**: 1, 153.

Eckert, J. E. and H. W. Allinger. 1935. Airplane dusting and its relation to beekeeping. JOUR. ECON. ENT. **28**: 3, 590–7.

Hoskins, W. M. and A. S. Harrison. 1934. The buffering power of the contents of the ventriculus of the honeybee and its effect upon the toxicity of arsenic. JOUR. ECON. ENT. **27**: 5, 924–42.

Nelson, R. W. 1938. Tartar emetic as a field spray against the gladiolus thrips. JOUR. ECON. ENT. **31**: 2, 208–11.

Persing, C. O., A. M. Boyce and F. G. McCarty. 1940. Field studies on control of citrus thrips on lemons and oranges. Calif. Citrograph, Part I March, **25**: 5, 134, 170–2; Part II April, **25**: 6, 176–7, 204–6.

Richardson, Henry W. 1934. Studies of derris, nicotine, paris green and other poisons in combination with molasses in the control of the gladiolus thrips. Jour. Agr. Res. **49**(4): 371.

Woglum, R. S. 1940. Citrus thrips in southern California. The Exchange Pest Control Circular No. **64**, April.

The Insecticidal Effects of Organic Compounds

1. Toxicity of sulfur and nitrogen compounds to fleshfly larvae[1]

W. M. HOSKINS, H. P. BLOXHAM[2] and MARIAN W. VAN ESS

INTRODUCTION.—The studies which are proceeding in many laboratories on the toxic effects of organic compounds toward insects have already provided an immense amount of data, but have led as yet to only a few generalizations regarding structure and toxicity which may be used for selection of materials for practical use. Among the numerous difficulties particular importance attaches to the multitude of compounds already known or possible to make, the lack of agreement on methods of testing and the use of insects of unknown physiological or genetic condition. Comparatively few species of insects are suitable for laboratory rearing over long periods and many economic species undergo a more or less compulsory dormant period during the winter, thereby introducing the probability of seasonal variations in susceptibility. In consequence of this situation an inordinate proportion of the toxicity studies has been made with the silkworm and with grain insects. An extreme method of avoiding the biological difficulties inherent with insects is the use of the goldfish, *Carassius auratus*, for evaluation of possible organic insecticides (Gersdorff, 1936; Gersdorff & Claborn, 1938).

The present work concerns feeding tests with larvae of the fleshfly *Lucilia sericata*. Several advantages in the use of this insect may be mentioned. It is easily reared throughout the year under standardized laboratory conditions (Dorman *et al.*, 1938) and the larvae thrive upon a simple synthetic diet (Michelbacher, *et al.* 1932). The life cycle is short and natural mortality is low. Parasites and diseases are of no importance. Any larval instar or any other stage of the life cycle may be obtained at will. Chemicals may be applied in various ways with all stages, *e.g.*, by contact, in-

[1] Contribution from the laboratory of insect physiology and toxicology, Division of Entomology and Parasitology, University of California.

[2] Employed by the Works Progress Administration and assigned to W.P.A. Official Project No. 65-1-08-91, Unit B-9, at the University of California.

jection, as a fumigant, and also in food of the larvae and adults.

EXPERIMENTAL PROCEDURES.—Eggs were obtained upon fishheads from females of the fly colony which has been inbred in this laboratory for ten years. Approximately 24 hours after hatching, by which time the larvae had reached the second instar, they were transferred in groups of fifteen into vials 21 by 75 mm. in which food plus the desired chemical had been placed. The amount of each ingredient in the food was as follows: technical powdered casein 3.0 gm, dried brewers' yeast 0.3 gm, butter 0.3 gm, 1 per cent agar solution 14.4 cc. The desired quantity of the chemical to be tested was placed in a large tube. The solid ingredients of the diet were then added and mixed thoroughly by means of a flattened glass rod. All solid substances tested were finely ground to facilitate uniform distribution through the food. The agar solution, warmed sufficiently for measurement in a pipette, was then added and stirred in very carefully. The food while still fluid was divided equally between three vials which were kept in a slanted position until their contents had set. Thus each test was performed in triplicate and repetitions were made when discrepancies occurred. For the extreme dilutions much larger amounts of food were made up and aliquot portions removed for the three vials.

On this standard synthetic diet second instar larvae begin to feed within a few hours and complete their feeding in four to five days when kept at 25 degrees C. The mortality on this standard diet in seven tests made at intervals during the course of the investigation varied from zero to 20 per cent, averaging 16 per cent. With both the standard and experimental diets daily observations were made and the number of living larvae recorded. When feeding was completed, the surviving larvae were transferred to clean dry vials and daily records made of survival and pupation. Lastly, the number of successful emergences was recorded. The mortality given in the following tables was calculated from the total number of deaths during all of these phases. Values given are the average of all runs.

With most of the chemicals tested the concentration was varied widely enough to include both high and low toxicities, but with compounds having but little effect only a few concentrations were tried. While it is recognized that the toxic effects of various chemicals may be compared most accurately from their entire concentration-mortality curves this is only possible when each is highly toxic at concentrations capable of use. Similar limitations apply to determination of the point of fifty per cent kill. Consideration of the data from the present work indicated that trends in the relations of chemical constitution to toxicity could be satisfactorily shown by comparison of the lowest concentration at which complete mortality occurred, together with the mortality at the next lower concentration. In the case of substances obviously only slightly toxic the mortality is given for only the highest concentration used. All diets were made up by weight and the geometric dilution method was used, *i.e.*, each concentration of the toxic substance was one half its value in the preceding test.

On account of the tremendous number of organic compounds, there is little hope of gaining an insight into the relations of structure to toxic action by selecting the chemicals for testing on the basis of availability or alphabetical arrangement. It is by examining groups of related but progressively differing substances that such information must be sought. But here again the number of substances suitable for trial is nearly unlimited. Studies by many investigators with numerous animals and plants have agreed in showing that the presence of nitrogen or sulfur in a compound is often associated with strong pharmacological effects. Ginsburg & Cavallito (1936) found that strong insecticidal action is frequently a property of compounds containing both nitrogen and sulfur. The present work was planned to include compounds of this type.

Chemicals were obtained from several sources. In so far as possible they were the Eastman Kodak Company's reagent grade. The research laboratories of several chemical companies supplied certain special compounds and nearly half the substances tested were synthesized in this laboratory by one of the authors (M.W. V.E.). Purity was established by analysis or other appropriate test. No claim is made that all the materials used were of C.P. quality but errors attributable to this cause are doubtless small.

RESULTS.—In preliminary work it was

found that thiourea is extremely toxic to *Lucilia sericata* under the conditions of these tests. This rather unexpected result caused the investigation to be turned toward derivatives of this compound and to related substances containing sulfur or nitrogen. Table 1 contains the data for several series. For comparison, the results with several inorganic compounds also are given and in Table 2 analogous oxygen and sulfur compounds are compared.

DISCUSSION.—Before considering the mortality resulting from the various chemicals used, certain characteristics of these tests should be mentioned. Fleshfly larvae lie almost completely imbedded in their food and hence a poison added to the latter may act by contact as well as by absorption from the gut and, of course, also as a fumigant if it is appreciably volatile. Except for ammonia, nicotine, propyl mercaptan and the low molecular weight amines the compounds used in these experiments have relatively high boiling points and the most toxic substances are non-volatile solids. Hence respiratory effects probably are negligible. The solubility varies enormously and doubtless is a limiting factor for the toxicity of some compounds, such as lead arsenate, rotenone and phenothiozine. The solubility of acidic or basic compounds and of many salts is affected by the pH of the medium to which they are exposed. At the beginning of an experiment the food was somewhat acidic (pH = 5 ±) but as the larvae fed they produced ammonia (Michelbacher *et al.*, 1932) and the pH rose to neutral or beyond. Consequently the solubility and the stability of many of the compounds used probably underwent a change.

With reference to contact insecticidal action the change in pH may play an important role, for the degree of ionization and hence the ease of penetration through the integument are affected thereby. Thus the molecular arsenious acid present in acidic solutions is more toxic than the arsenite ion of basic solutions toward mosquito pupae, and many other similar instances have been recorded (Hoskins 1932, 1940). Within the digestive tract of the larvae the pH is doubtless relatively independent of the nature of the food although in severe poisoning of the larvae of *Euxoa segetum* and *Pieris brassicae* by sodium arsenite or paris green marked departure

Table 1.—Mortality resulting from addition of inorganic or organic compounds to synthetic diet for *Lucilia sericata* larvae.

COMPOUNDS	MORTALITY AT INDICATED CONCENTRATIONS		
Name and formula	Conc. in per cent by weight	Mortality in per cent	Stages[1]
Standard diet		16	2,3,4
I. *Inorganic compounds*			
sodium arsenite	1/32	100	3,4,p
Na_3AsO_3	1/64	87	3,4
sodium arsenate	1/8	100	2,3
Na_2AsO_4	1/16	80	2,3,4,p
calcium arsenate	1/32	92	2,3
$Ca_3(AsO_4)_2$ (technical)	1/64	42	2,3
lead arsenate, standard	1/32	25	2
$PbHAsO_4$	1/64	26	2
cryolite	1/32	42	2,3
Na_3AlF_6 (technical)	1/64	26	2
sodium sulfide	1/2	51	3,4
Na_2S (technical)	1/4	29	3,4,p
boric acid	1/8	100*	2
H_3BO_3	1/16	93	2,3,4,p
II. *Organic compounds*			
Miscellaneous			
rotenone	1/128	100	2,3
$C_{23}H_{22}O_6$	1/256	98	2,3,p
	1/512	62	2,3,4
nicotine	1/64	100	2
$C_{10}H_{14}N_2$	1/128	47	2,3
2,4-dinitro-6-cyclohexylphenol	1/128	93	2,3
$C_6H_2(NO_2)_2(OH)C_6H_{11}$	1/256	87	2,3
Lethane 384 (50% β-butoxy-β'-thiocyanodiethyl ether)	1/8	100	3,4
$C_4H_9OCH_2CH_2OCH_2CH_2SCN$	1/16	93	3,4,p
xanthone	1/8	58	2,3
$C_6H_4OC_6H_4CO$			
Amines			
n-butylamine	1/2	20	2,3,p
$CH_3(CH_2)_3NH_2$			
di-*n*-butylamine	1/8	100	3
$[CH_3(CH_2)_3]_2NH$	1/16	87	3
tri-*n*-butylamine	1/8	100	2,3
$[CH_3(CH_2)_3]_3N$	1/16	47	2,3
n-amylamine	1/8	36	2
$CH_3(CH_2)_4NH_2$	1/16	20	2
di-*n*-amylamine	1/8	73	2,3
$[CH_3(CH_2)_4]_2NH$	1/16	49	2,3
n-heptylamine	1/8	51	2,3,p
$CH_3(CH_2)_6NH_2$			
dodecylamine	1/2	87	2,3
$CH_3(CH_2)_{11}NH_2$			
amine 220[2]	1/2	24	2,3
aniline	1/8	100*	2
$C_6H_5NH_2$	1/16	89	2,3,4
diphenylamine	1/4	100	2,3
$(C_6H_5)_2NH$	1/8	51	2,4,p
triphenylamine	1/4	18	2
$(C_6H_5)_3N$			
n-butylaniline	1/8	100*	2
$C_6H_5NH(CH_2)_3CH_3$	1/16	69	2,3,4,p
benzylaniline	1/4	93	2,3
$C_6H_5NHCH_2C_6H_5$	1/8	60	2,3,p
o-phenylenediamine	1/8	100	2,3
$C_6H_4(NH_2)_2$	1/16	44	2,3,p
morpholine	1/4	100	2,3,4
$CH_2CH_2NHCH_2CH_2O$	1/8	62	2,3,4
Mercaptans			
n-propyl mercaptan	1/2	24	3,4,p
$CH_3CH_2CH_2SH$			
thiophenol	1/4	100	2
C_6H_5SH	1/8	91	3,4
o-thiocresol	1/4	100	2
$CH_3C_6H_4SH$	1/8	95	2,3,p
m-thiocresol	1/8	100	4
$CH_3C_6H_4SH$	1/16	53	4,p
p-thiocresol	1/8	100	2,3
$CH_3C_6H_4SH$	1/16	62	2,4,p
benzyl mercaptan	1/8	100	2,3
$C_6H_5CH_2SH$	1/16	76	2,3,p
Monosulfides			
methyl ethyl sulfide	1/2	91	3,4,p
$CH_3SCH_2CH_3$	1/4	47	3,4,p

(*Table continued on next page*)

Table 1—Continued

Compounds	Mortality at Indicated Concentrations		
Name and formula	Conc. in per cent by weight	Mortality in per cent	Stages[1]
ethyl *n*-butyl sulfide $CH_3CH_2S(CH_2)_3CH_3$	1/2	55	3,4,p
n-butyl sulfide $[CH_3(CH_2)_3]_2S$	1/2	62	4,p
n-amyl sulfide $[CH_3(CH_2)_4]_2S$	1	60	3,4,p
ethyl benzyl sulfide $CH_3CH_2SCH_2C_6H_5$	1/4	100	3,4
	1/8	95	3,4
ethyl *p*-tolyl sulfide $CH_3CH_2SC_6H_4CH_3$	1/4	98	3,4,p
	1/8	42	4,p
p-tolyl sulfide $[CH_3C_6H_4]_2S$	1/2	100	2,3
	1/4	71	4,p
phenothiazine (thiodiphenylamine) $C_6H_4SC_6H_4NH$	1/8	100	2,3
	1/16	84	2,3,p
phenoxathiin (phenoxthin) $C_6H_4SC_6H_4O$	1/16	100	2
	1/32	98	2
	1/64	24	2,p
Disulfides			
n-butyl disulfide $CH_3(CH_2)_3SS(CH_2)_3CH_3$	1/4	100	3,4,p
	1/8	80	3,4
phenyl disulfide $C_6H_5SSC_6H_5$	1/4	100	3
	1/8	60	4,p
p-tolyl disulfide $CH_3C_6H_4SSC_6H_4CH_3$	1/4	100	3
	1/8	93	4,p
benzyl disulfide $C_6H_5CH_2SSCH_2C_6H_5$	1	49	3,4,p
	1/2	22	3,4,p
Thioacid derivatives			
thioacetamide CH_3CSNH_2	1/32	100	2,3
	1/64	91	2,3,p
N-allylthioacetamide $CH_3CSNHCH_2CH=CH_2$	1/128	100	2,3,4,p
	1/256	91	2,3,4,p
thioacetanilide $CH_3CSNHC_6H_5$	1/16	100	2,3
	1/32	78	2,3,p
thiopropionamide $CH_3CH_2CSNH_2$	1/64	100	2,3
	1/128	69	2,3,4
N-allylthiopropionamide $CH_3CH_2CSNHCH_2CH=CH_2$	1/128	100	2,3,4,p
	1/256	64	2,3,4,p
thiophenylacetamide $C_6H_5CH_2CSNH_2$	1/16	100	2,3
	1/32	78	2,3
thiobenzanilide $C_6H_5CSNHC_6H_5$	1/4	100	2,3,4
	1/8	62	2,3,4,p
n-butyl thiolacetate $CH_3COSCH_2(CH_2)_4CH_3$	1/4	100	3
	1/8	84	4,p
amyl thiolacetate[3] $CH_3COSCH_2(CH_2)_3CH_3$	1/2	98	3,4
	1/4	84	3,4,p
sodium diethyl dithiocarbamate $(CH_3CH_2)_2NCSSNa$	1/8	93	2,3,4,p
	1/16	73	2,3,4,p
tetramethylthiouram disulfide $(CH_3)_2NCSS\text{-}SCSN(CH_3)_2$	1/8	84	2,3
	1/16	53	2,3
Thioureas			
thiourea NH_2CSNH_2	1/128	100	2,3
	1/256	100	2,3,p
	1/512	85	2,3,4
1-methyl-2-thiourea $NH_2CSNHCH_3$	1/128	100	2,3,4,p
	1/256	93	2,3,4,p
1-ethyl-2-thiourea $NH_2CSNHCH_2CH_3$	1/128	100	2,3,4,p
	1/256	60	2,4,p
1-*n*-propyl-2-thiourea $NH_2CSNHCH_2CH_2CH_3$	1/128	100	2
	1/256	84	2,3,4,p
1-*n*-butyl-2-thiourea $NH_2CSNHCH_2(CH_2)_2CH_3$	1/256	100	2,3,4,p
	1/512	89	2,3,4,p
1-*n*-amyl-2-thiourea $NH_2CSNHCH_2(CH_2)_3CH_3$	1/64	100	2,3,4
	1/128	89	2,3,4
1-*n*-heptyl-2-thiourea $NH_2CSNHCH_2(CH_2)_5CH_3$	1/32	100	2,3,4,p
	1/64	93	2,3,4
1-dodecyl-2-thiourea[4] $NH_2CSNHCH_2(CH_2)_{10}CH_3$	1/16	51	2,3,4
	1/32	40	2,3,4
1-phenyl-2-thiourea $NH_2CSNHC_6H_5$	1/16	100	2,3
	1/32	73	2,3,4,p
1-(*o*-tolyl)-2-thiourea $NH_2CSNHC_6H_4CH_3$	1/8	53	2,3
1-(*p*-bromophenyl)-2-thiourea $NH_2CSNHC_6H_4Br$	1/64	36	2,4
1,3-dimethyl-2-thiourea $CH_3NHCSNHCH_3$	1/128	100	2,3
	1/256	100	2,3,4
	1/512	38	2,4
1,3-diethyl-2-thiourea $CH_3CH_2NHCSNHCH_2CH_3$	1/64	94	2,3,4
	1/128	80	2,3,4
1,3-di-*n*-butyl-2-thiourea $CH_3(CH_2)_2CH_2NHCSNH\text{-}CH_2(CH_2)_2CH_3$	1/16	80	2,3
1,3-didodecyl-2-thiourea[5] $CH_3(CH_2)_{10}CH_2NHCSNH\text{-}CH_2(CH_2)_{10}CH_3$	1/16	42	2,3

Table 1—Continued

Compounds	Mortality at Indicated Concentrations		
Name and formula	Conc. in per cent by weight	Mortality in per cent	Stages[1]
1,3-diphenyl-2-thiourea $C_6H_5NHCSNHC_6H_5$	1/2	36	2,3
1,3-ethylene-2-thiourea $CH_2NHCSNHCH_2$	1/256	100	2,3
	1/512	42	2,3,4
1,3-(*o*-phenylene)-2-thiourea $C_6H_4NHCSNH$	1/8	93	2,3,4
	1/16	84	2,3,4
1-acetyl-2-thiourea $NH_2CSNHCOCH_3$	1/64	100	2
	1/128	84	2,3
1-(2-furoyl)-2-thiourea $NH_2CSNHCO(C_4H_3O)$	1/64	80	2,4,p
1-benzoyl-2-thiourea $NH_2CSNHCOC_6H_5$	1/16	100	2
	1/64	78	2,3,4,p
1,3-diacetyl-2-thiourea $CH_3CONHCSNHCOCH_3$	1/128	100	2,3
	1/256	80	2,3,4,p
1,3-malonyl-2-thiourea (2-thiobarbituric acid) $NHCSNHCOCH_2CO$	1/8	22	2
2-methyl-2-thiourea sulfate $[NH_2C(SCH_3)NH]_2SO_4$	1/16	60	2,3
pseudothiohydantoic acid $NH_2C(SCH_2COOH)NH$	1/8	16	2
pseudothiohydantoin $NHC(NH)SCH_2CO$	1/8	100	2,3,p
	1/16	93	2,3,p

* Indicates no apparent feeding

[1] 2,3,4, indicate that death occurred in the second, third or fourth larval instar.

[2] the free base of an amino condensation product of oleic acid.

[3] made from a mixture of isomeric amyl mercaptans.

[4] 1-Dodecyl-2-thiourea (apparently hitherto undescribed) was prepared by the reaction of dodecyl isothiocyanate with ammonium hydroxide; white flakes, mp. 106–7° (crystallized from ethanol).

Anal. Calcd. for $C_{13}H_{28}N_2S$: N, 11.46. Found: N, 11.44.

[5] 1,3-Didodecyl-2-thiourea (apparently hitherto undescribed) was prepared from dodecyl amine and carbon disulfide by a method based on that of Skita and Rolfes, *Ber. 53*, 1247 (1920); white-granules, mp. 69–70° (crystallized from ethanol).

Anal. Calcd. for $C_{25}H_{52}N_2S$: N, 6.79. Found: N, 6.63.

Table 2.—Mortality resulting from addition of analogous oxygen and sulfur compounds to synthetic diet for *Lucilia sericata* larvae.

Compounds	Mortality at Indicated Concentrations		
Name and formula	Conc. in per cent by weight	Mortality in per cent	Stages
phenol C_6H_5OH	1/2	100*	2
	1/4	47	2,3,p
thiophenol C_6H_5SH	1/4	100	2
	1/8	91	3,4
o-cresol $CH_3C_6H_4OH$	1/2	100*	2
	1/4	85	2,3,p
o-thiocresol $CH_3C_6H_4SH$	1/4	100	2
	1/8	95	2,3,p
urea NH_2CONH_2	1/2	18	2,3
thiourea NH_2CSNH_2	1/256	100	2,3
	1/512	85	2,3,4
acetamide CH_3CONH_2	1/2		2,3,p
thioacetamide CH_3CSNH_2	1/32	100	2,3
	1/64	91	2,3,p
xanthone $C_6H_4COC_6H_4O$	1/8	58	2,3
xanthione $C_6H_4CSC_6H_4O$	1/16	33	2,p
thioxanthone $C_6H_4COC_6H_4S$	1/8	20	2

* Indicates no apparent feeding.

from the normal alkaline condition of the midgut was found (Skrjabina, 1936). It is known that the midgut of *Lucilia sericata* larvae normally has a region of high acidity (Hobson, 1931) but no data appear to be available on the buffering power of the digestive juices nor on the effects of poisons on this or any other region of the digestive tract. Until physiological information of this kind is available the results of toxicity investigations must be correlated and interpreted very largely in terms of the chemical properties of the substances concerned.

Although the results as given in the tables are more or less self-explanatory certain comments and comparisons within and among the various classes of compounds may be made. In conformity with the usual experimental findings, sodium arsenite is several times as toxic as sodium arsenate and the slightly soluble calcium and lead arsenates are relatively non-toxic.

Results obtained with several well known organic insecticides are included in order to provide a basis for judging the effectiveness of the compounds investigated. In the following discussion it must be remembered that the validity of any generalizations has been established only for the substances tested. While they probably hold in a broader sense, there is always the possibility of specific exceptions.

The primary amines are all relatively non-toxic but in passing down the series there is a maximum at or near *n*-heptylamine followed by a decline to practically no effect with amine 220. In the series of straight chain secondary amines the maximum toxicity occurs at di-*n*-butylamine, or possibly lower since di-*n*-propylamine has not been tested. Secondary aliphatic amines are much more active than the corresponding primary amines. Among the aromatic amines a different situation prevails. The toxic effect drops steadily from aniline to triphenylamine. This latter compound was found by Fink, *et al.* (1938) to be non-toxic to mosquito larvae at the highest concentration used in their work, and diphenylamine has no effect on the silkworm (Ginsburg & Granett, 1935).

The mercaptans and monosulfides are all relatively non-toxic, and are surpassed by the disulfides. The low toxicity of benzyl disulfide is in agreement with the result of Campbell, *et al.* (1934) with culicine mosquito larvae. Phenothiazine, which might be regarded as a cyclic sulfide, is moderately toxic, producing about the same mortality as sodium arsenate or as *Lethane*. Phenoxathiin is nearly as lethal as sodium arsenite and unlike phenothiazine, does not give rise to objectionable colored oxidation products.

The group -C (=S) NH- gives rise to a number of highly toxic compounds, including the thioureas, which will be discussed later, and the thioamides. Both the thioacetamide and thiopropionamide become more toxic with the introduction of an allyl group on the nitrogen atom, but similar substitution by a phenyl radical in thioacetamide causes a decrease. This condition is opposite to that observed with the silkworm (Ginsburg & Cavallito, 1936). Some other thioacid derivatives were less promising. Esters of thiolacetic acid were ineffective. Tetramethylthiouram disulfide, which is repellent to silkworms (Ginsburg & Granett, 1935) and to the Mexican bean beetle, *Epilachna varivestis*, and other leaf-eating beetles (Guy, 1937) is somewhat toxic to fleshfly larvae but not noticeably repellent at one-eighth per cent. Sodium diethyl dithiocarbamate gave a similar though more delayed mortality.

In connection with these varied sulfur compounds, it is of interest to compare analogous sulfur and oxygen compounds as in table 2. The aryl mercaptans are uniformly more toxic than the corresponding phenols, but it is in the replacement of carbonyl oxygen by sulfur that the greatest increment is observed, particularly in urea and acetamide. Though replacement of the carbonyl oxygen atom of xanthone to form xanthione also results in a slight increase in toxicity, the replacement of the heterocyclic oxygen atom to form thioxanthone has an opposite effect.

The outstanding feature of this investigation to date is the high toxicity of thiourea. On the basis of the concentration required for 95 to 100 per cent mortality, thiourea and several of its derivatives are as effective as rotenone or 2,4-dinitro-6-cyclohexylphenol and distinctly more toxic than *Lethane* or nicotine. The simple mono-alkyl derivatives resemble thiourea in their lethal effects, but their effect is often delayed so that many insects exposed to propyl, butyl and amyl thioureas

died in the fourth instar or as pupae. The maximum toxicity for this series appears to occur with mono-*n*-butyl thiourea which causes approximately the same mortality as thiourea itself. The monoalkyl thioureas of higher molecular weight are decidedly less effective. The introduction of even one phenyl radical also reduces toxicity, an observation in harmony with the findings with thioacetamide where it was also noted that the substitution of a phenyl radical for a hydrogen atom of the amino group resulted in decreased mortality. Symmetrical diphenyl thiourea is even less toxic. The symmetrical diaryl and dialkyl thioureas are uniformly less toxic than the corresponding monosubstituted derivatives, a result which agrees with the change in mothproofing potency of some of these compounds (Minaeff & Wright, 1929). Among the aliphatic derivatives this factor assumes diminishing importance as the molecular weight decreases. Consequently it is not surprising to find that 1,3-ethylene-2-thiourea is extremely toxic, 1,3-(*o*-phenylene)-2-thiourea, like other aromatic derivatives is relatively ineffective. In the few cases examined, the substitution of groups on the sulfur atom to form compounds of the pseudothiourea type resulted in large losses of toxicity. The acyl derivatives of thiourea were ineffective with the exception of the simple mono- and diacetyl thioureas.

Speculation regarding the great toxicity of thiourea gives rise to certain interesting points. In the first place it appears to be highly repellent though experimental conditions make it difficult to distinquish between repellency and very rapid lethal action. No observable feeding occurred with a concentration of one one hundred and twenty-eighth per cent or greater. At the next dilution, which still allows no survival, some feeding occurred, and the last instar was reached by some individuals at one and one five hundred and twelfth. An indication that failure to feed is not the chief cause of mortality at low concentrations is given by an experiment in which third instar larvae, approximately half grown, were placed upon food containing thiourea at a concentration of one thirty-second. The larvae fed but died in the third and fourth instars. Since half grown larvae are able to live for many days and usually are able to pupate if given no more food it is obvious that their speedy death was directly due to the poison. Certain other instances of marked repellancy (or very early death) are shown in the tables and much data on this subject is being collected in the course of the toxicity experiments. Preliminary studies of the toxicity of thiourea toward house-fly larvae (*Musca domestica*) have indicated that this insect also is very sensitive to the compound and the possibility of a practical means of control suggests itself.

Experiments in this laboratory as well as those of others (*e.g.*, Ginsburg & Cavallito, 1936) have shown that thiourea and derivatives have very little toxicity toward certain leaf eating insects. It is also only slightly toxic for adult flesh flies. Hence, the relation seems to hold that thiourea has but slight effect upon insects whose diet is largely carbohydrate, but is very toxic for those, such as the larvae of fleshflies and clothesmoths, which live upon a predominantly protein diet. The possibility may be suggested that an enzyme concerned with the metabolism of protein may be affected adversely by these compounds.

SUMMARY.—The toxicity to larvae of the fleshfly, *Lucilia sericata*, of representatives from several series of organic compounds containing amino nitrogen or sulfur or both has been studied by adding the substances at various concentrations to a synthetic diet. Di- and trialiphatic amines are more toxic than the monoamines, but the reverse relation holds with the aromatic amines. Mercaptans and monosulfides are relatively non-toxic. Disulfides are more toxic than monosulfides. The group -C (=S) N= gives rise to highly toxic compounds, especially thiourea, certain of its derivatives and certain thioamides. Introduction of a phenyl group upon the nitrogen reduces toxicity. Substitution upon the sulfur atom reduces the toxic effect. Since thiourea has little toxicity to leafeating insects, but is very effective against fleshfly larvae and clothes moth larvae, it may be that the mechanism of its poisonous action is to be sought in the behavior of the enzymes concerned in the metabolism of a highly proteinaceous diet.[3]—7-15-40.

[3] The assistance of the following chemical companies who furnished samples of their products is greatfully acknowledged, Shell Development Company, Sharples Solvents Corporation, Carbide and Carbon Chemicals Corporation.

LITERATURE CITED

Campbell, F. L., W. N. Sullivan, L. E. Smith and H. L. Haller. 1934. Insecticidal tests of synthetic organic compounds chiefly tests of sulfur compounds against culicine mosquito larvae. JOUR. ECON. ENT. **27**: 1176–85.

Dorman, S. C., W. C. Hale and W. M. Hoskins. 1938. The laboratory rearing of fleshflies and the relations between temperature, diet and egg production. JOUR. ECON. ENT. **31**: 44–51.

Fink. D. E., L. E. Smith, D. L. Vivian and H. V. Claborn. 1938. Toxicity tests with synthetic organic compounds against culicine mosquito larvae. U. S. Dept. Agr. E-425.

Gersdorff, W. A. 1936. Relative toxic action of phenol and phenyl mercaptan when the gold fish is used as the test animal. Jour. Agr. Res. **53**: 841–7.

Gersdorff, W. A. 1939. Effect of introduction of the nitro group into the phenol molecule on toxicity to goldfish. Jour. Cell Comp. Physiol. **14**: 61–71.

Gersdorff, W. A., and H. V. Claborn. 1938. The toxicity of phenothiazine and some of its oxidation products in experiments with *Carassius auratus*. Jour. Agr. Res. **56**: 277–82.

Ginsburg, J. M. and C. J. Cavallito. 1936. Arsenical substitutes II. JOUR. ECON. ENT. **21**: 856–9.

Ginsburg, J. M. and P. Granett. 1935. Arsenical substitutes I. JOUR. ECON. ENT. **28**: 292–8.

Guy, H. G. 1937. Investigation of organic compounds as insecticides. Del Agr. Expt. Sta. Bull. No. 206 (Tech. No. 19).

Hobson, R. P. 1931. Studies on the nutrition of blowfly larvae I. Jour. Exp. Biol. **8**: 109–23.

Hoskins, W. M. 1932. Toxicity and permeability I. The toxicity of acid and basic solutions of sodium arsenite to mosquito pupae. JOUR. ECON. ENT. **25**: 1212–24.

Hoskins, W. M. 1940. Recent contributions of insect physiology to insect toxicology and control. Hilgardia **13**: 307–86.

Michelbacher, A. E., W. M. Hoskins and W. B. Herms. 1932. The nutrition of fleshfly larvae, *Lucilia sericata* Meig. I. Jour. Exp. Zool. **64**: 110–30.

Minaeff, M. G. and J. H. Wright. 1929. Mothproofing. Jour. Ind. and Eng. Chem. **21**: 1187–95.

Skrjabina, E. 1936. The mechanism of insecticidal action. (In Russian.) Plant Protection Ser. III **7**: 9–24.

Experiments with Derris and Cubé Dusts for Pea Weevil Control

T. A. BRINDLEY, F. G. HINMAN and R. A. FISHER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Prior to the summer of 1934 insecticides were considered to be of little value in the control of the pea weevil, *Bruchus pisorum* (L.). In that year calcium arsenate was used to some extent in the Willamette Valley in Oregon, and Larson *et. al.* (1938) showed that when it was applied to Austrian Winter field peas, although weevil populations were not eliminated, the germination and weight of the peas were increased to the point where they would pass regulatory measures in these respects. Laboratory and field tests in the seed-pea areas near Moscow, Idaho, showed calcium arsenate to be ineffective. More recent experiments with several other insecticides, however, demonstrated that derris and cubé dusts were effective, and these materials have since been used in the commercial control of the weevil.

LABORATORY TESTS.—During the summer of 1934 a series of preliminary laboratory tests was run to compare the effectiveness of the following insecticidal dusts: Calcium arsenate undiluted, barium fluosilicate, derris root mixed with sufficient diatomaceous earth to give a rotenone content of 1 per cent, and a mixture of equal parts of derris diluted with tobacco dust to give a rotenone content of 1 per cent and pyrethrum diluted with diatomaceous earth to give a total pyrethrin content of 0.45 per cent. Each material was tested by dusting directly on the insects; by exposing undusted weevils to blossoms from dusted plots; by exposing undusted weevils to blossoms dusted in the laboratory; and by compelling weevils to walk a distance of 2 inches over a dusted surface.

The insects, blossoms, and surfaces were dusted with a hand duster at the rate of approximately 20 pounds per acre. Only those insects or blossoms that were well covered with the insecticide were used. Weevils were placed individually in shell vials for observation. Treated weevils were put on untreated blossoms and untreated weevils on freshly treated blossoms. All weevils were supplied blossoms each day after the first 24 hours until the insects in an unfed check were dead.

A summary of the results of these tests is presented in table 1.

Table 1.—Summary of results of laboratory tests with insecticides against the pea weevil, Moscow, Idaho, 1934.

Treatment	Per Cent Mortality of Weevils			
		From Dusted Blossoms		Walked over Dusted Surface
	Dusted Directly	Field	Laboratory	
Calcium arsenate	34	96	38	2
Barium fluosilicate	34	97	43	69
Derris plus diatomaceous earth	97	94	100	77
Derris plus tobacco, pyrethrum plus diatomaceous earth	97	94	99	100

It is obvious from these tests that the inorganic insecticides did not give satisfactory kills and that the derris and pyrethrum dusts gave the best results.

PLOT TESTS.—During the crop season of 1935 the following insecticides were tested on fortieth-acre plots: Calcium arsenate, undiluted synthetic cryolite, derris and tobacco dust mixture containing 1 per cent of rotenone, derris and diatomaceous earth mixture containing 1 per cent of rotenone, and the combined mixture of derris and pyrethrum used in the laboratory tests. Each plot was dusted five times beginning on June 11, just prior to the formation of the first small pods. The subsequent applications were made on June 13, 15, 20, and 25.

Although none of the materials gave satisfactory control, owing to migration of weevils from undusted check areas, the combined mixture of derris and pyrethrum gave the best results and the mixture of derris and tobacco dust was second.

During that season two small garden patches were treated three times with the derris and tobacco dust mixture. Examination of the ripe peas from these patches showed 96 and 99.4 per cent to be sound. In an undusted garden patch in the same vicinity only 31.4 per cent of the seeds were sound.

Table 2.—Summary of results of plot-dusting experiments against the pea weevil, Moscow, Idaho, 1936.

Treatment	Green Peas		Dry Peas	
	Infestation	Control	Infestation	Control
Calcium arsenate-sulfur 1–5	17.15%	59.65%	17.03%	61.40%
Paris green-lime 1–5	6.20	85.41	7.34	83.41
Cryolite	1.06	97.51	1.36	96.93
Derris-tobacco dust (1% rotenone)	.16	99.62	.54	98.78
Derris-diatomaceous earth (0.5% rotenone)	.28	99.34	.55	98.76
Derris-diatomaceous earth (1% rotenone)	.21	99.51	.93	97.90
Derris-sulfur (1% rotenone)	*	*	1.12	97.47
Check	42.50	—	44.25	—

* No green-pea samples taken.

In 1936 tests were conducted on quarter-acre plots and mainly for the purpose of obtaining additional information on the effectiveness of derris. Mixtures of derris with tobacco dust, sulfur, and diatomaceous earth as diluents were used, as well as calcium arsenate and sulfur, paris green and lime, and undiluted synthetic cryolite. The materials were applied with hand dusters, at the rate of 20 pounds per acre, to peas that had been sown broadcast. Five dustings were made. Peas were examined in both the green-pod and dry stages. The results of these tests are given in table 2.

Table 3.—Reduction of pea weevil infestation in garden patches following applications of derris dust, Moscow, Idaho, 1936.

Treatment	Number of Patches	Average Eggs on 50 Pods	Average Infestation	
			Green Peas	Dry Peas
Dusted	13	8.04	1.21%	1.43%
Not dusted	5	274.62	33.14	41.34
Per cent control		97.1	96.3	96.5

In these tests the best results were obtained with the derris dusts, which gave controls of more than 99 per cent on green peas and from 97.47 to 98.78 per cent on dry peas. These figures were especially indicative, for the infestation on the immediately adjacent check plots averaged 42.50 per cent for the green peas and 44.25 per cent for the dry peas. The poorest results were obtained with calcium arsenate. Although the results with cryolite were very good, this material was not further investigated because of the possibility of harmful residues on the edible product.

In addition to these large-plot tests 13 garden patches were dusted. Derris mixtures containing 1 per cent of rotenone were applied to each patch. The first application was made just before the first small pods appeared on the vines, and applications were made thereafter whenever a 5-minute examination of the vines showed more than one weevil. The number of applications ranged from two to

five. The dust was applied with hand dusters at such a rate that it could readily be detected on the vines.

A summary of the results of these tests is presented in table 3.

The best results so far as the green-pea crop was concerned were obtained on a garden patch in which 117 weevils were found before the first dusting and no weevil-infested peas found after dusting. Ripe peas from this patch, however, showed an infestation of 3.2 per cent, an indication that dusting operations had been discontinued at too early a date.

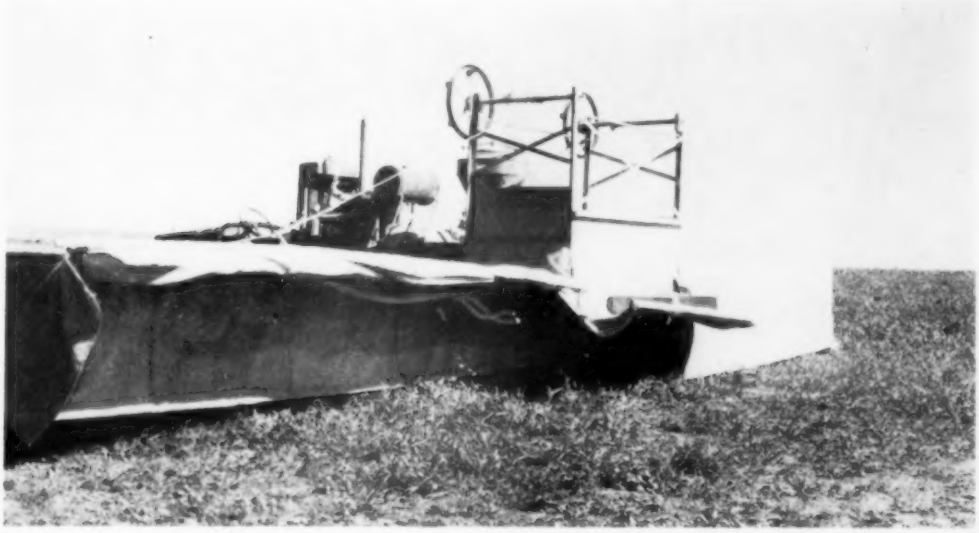


FIG. 1.—Duster of the type used in pea weevil control in 1937, showing the construction of the hood over the dust nozzles.

FIELD TESTS IN BORDER-TRAP STRIPS—In 1936, through the cooperation of a cannery, tests were made on a number of border-trap strips treated with a commercial cubé dust mixture stated by the manufacturers to contain between 0.65 and 0.8 per cent of rotenone in clay.

Border-trap strips (Larson, Brindley & Hinman 1938) are plantings of early pea varieties that develop ahead of the main field and serve to concentrate the weevils where they can be destroyed before the plants in the main field bloom. These strips are usually one drill (10 feet) wide and extend all the way around the field.

The dust was applied with land dusters, and in most instances the strips were plowed under the day the dust was applied; consequently no direct check could be made on the reduction in weevil population due to dusting. In two instances where it was possible to sweep the peas on the day following dusting, reductions of 88 and 94 per cent were indicated. In the first instance the actual reduction was probably greater than 90 per cent, because road dust, resulting from heavy traffic on a dirt road paralleling the edge of the field, settled on an undusted section of the border and caused some of the weevils to move over into the area that had been dusted the day previously with the rotenone compound.

OBSERVATIONS OF COMMERCIAL DUSTING IN 1937.—Approximately 95,000 pounds of dust mixtures containing rotenone and extractives derived from derris and cubé were applied to several thousand acres of commerical pea fields in 1937.

The fields in which observations were made were treated with cubé dust mixtures containing 1 and 0.75 per cent of rotenone. The dust was usually applied at the rate of 25 to 40 pounds per acre.

All the early dusting and some throughout the entire season was done by commercial-type dusters about 10 feet wide, drawn by horses, tractors, or trucks. Later, following the recommendations of the Oregon Agricultural Experiment

Station, some of the dusters were widened and equipped with hoods which covered the nozzles and confined the dust mixture to the plants.

These hoods were made of heavy cloth in the form of an elongated, inverted box, 3 to 4 feet high, 4 to 5 feet wide, and projecting 10 to 20 feet on each side of a truck

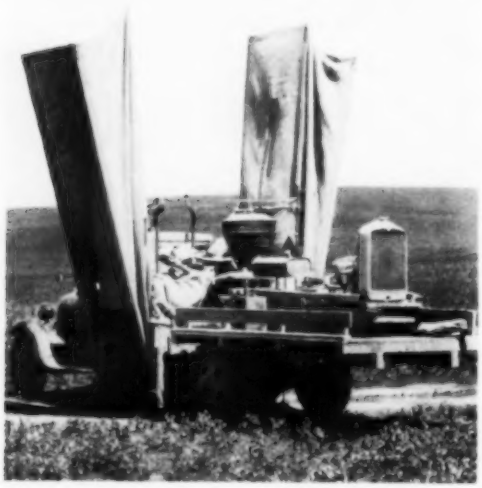


FIG. 2.—Duster with the hood raised to a vertical position. The dust nozzles are along the upper side of the hood and are not shown in the picture.

or trailer (Fig. 1). The bottom of the hood was weighted with iron rods or some heavy material to prevent whipping by the wind. Most of the hoods were so constructed that they could be raised to a vertical position when not in use (Fig. 2).

Hoods were first used on dusting machines for the control of the pea weevil in 1937 in western Oregon (Chamberlin & Gray 1938). They were based on the principle of the hooded oil atomizer which has been employed in control studies of the beet leafhopper in Idaho and California.

To determine the effect of the dusts the weevils were collected in an insect net before and after dusting, 500 sweeps of the net being made each time. Observations were made in only a portion of each field, a distance of 1,000 or more feet being covered in 500 sweeps. Twenty-five sweeps constituted a sample. A stake was set up to mark the point where each fiftieth sweep was taken, thereby making it possible to return to a field and sample the same area that had been swept previously.

Sweeping was done along the edges of the fields and within the fields for a distance of 100 feet parallel to the edge. If a border-trap strip had been planted, sweeping was done on this strip and also within the field for 100 feet.

The fields were swept every 3 days throughout the blooming period, except when weather conditions prevented. In fields with border-strip plantings sweeping was begun in the main field before the plants began to bloom. The fields were swept the day after the dust was applied.

Table 4.—Average number of pea weevils per sample in twenty 25-sweep samples before and after dusting with cubé mixtures in various commercial fields in the Blue Mountain area of Washington and Oregon, 1937.

Dusters with Hoods		Dusters without Hoods	
Number of Weevils		Number of Weevils	
Before Dusting	After Dusting	Before Dusting	After Dusting
Mixtures containing 1 per cent of rotenone		*Mixtures containing 1 per cent of rotenone*	
63.05	0.35	101.45	1.55
46.30	.30	48.85	1.90
42.25	.20	35.00	1.75
23.15	.15	32.30	2.30
21.80	.30	13.10	.30
14.55	.10	11.40	.30
8.10	.30	9.20	.35
6.35	.20	8.75	1.00
4.60	.10	7.35	1.35
4.10	.00	4.35	.25
4.10	.00	1.50	.00
1.90	.00	1.50	.05
1.55	.00		
1.20	.10	*Mixtures containing 0.75 per cent of rotenone*	
1.15	.00	22.15	.25
1.10	.00	14.20	1.05
Mixtures containing 0.75 per cent of rotenone		13.45	.60
42.80	.00	4.05	1.20
27.25	.25	2.05	.15
26.55	.05		
21.65	.90		
18.00	.15		
7.25	.15		
5.80	.25		
3.45	.10		
1.85	.05		
1.20	.00		
1.20	.00		
1.05	.05		

Table 4 shows the reduction in weevil populations following dusting with the two concentrations of cubé dust when applied with and without hoods over the dust nozzles.

FIG. 3.—Duster with trailer used in pea weevil control in 1938.

From these data the mean percentage reductions in weevil population due to dusting have been calculated and an analysis of the results is given in table 5.

Table 5.—Percentage reductions in pea weevil populations following applications of cubé dust mixtures in commercial fields, Blue Mountain area of Washington and Oregon, 1937.

Type of Duster	Average Reduction in Population, Per Cent		
	1 Per Cent of Rotenone	0.75 Per Cent of Rotenone	Difference, Per Cent
With hood	98.64	98.10	0.54±0.78
Without hood	94.57	90.01	4.55±3.85
Difference, per cent	4.07±1.40†	8.09±3.21*	

* Significant.
† Highly significant.

The use of hoods definitely increases the degree of control, since there are significant differences between the results with hooded dusters and those with dusters not having hoods. The data indicate no significant difference, however, between dusts containing 1 per cent of rotenone and those containing 0.75 per cent of rotenone whether applied with or without hoods on the machines.

Good control was achieved only when the duster passed over the entire infested area. In one field untreated strips about 30 feet wide were left between the dusted strips. Although a heavy application of dust was used, the reduction in weevils on the undusted strips was only approximately 82 per cent. The day was quiet, however, and the dust drifted slowly across the field.

No direct evidence of any repellent action of the dust was found. In several instances, particularly early in the season when migration to the pea field is most general, increased numbers of weevils were noted within a day after dusting. Observations indicate that such increases are due to movements of weevils into the field after the rotenone dusts have lost a part of their effectiveness.

OBSERVATIONS OF COMMERCIAL DUSTING IN 1938.—During the 1938 crop season over 400,000 pounds of commercial dusts containing 1 per cent of rotenone derived from derris, cubé, and timbo were used for weevil control. Most of this dust was applied early in the season, when some entire fields had to be treated to control the widely scattered weevils. Continued migrations from hibernation quarters to pea fields necessitated two and sometimes three dustings.

Most of the dusters used that year were equipped with a short trailing canvas (Fig. 3), which aided in preventing the dust from being blown by the wind. These trailers did little or no injury to the pea vines.

Control throughout the season was uniformly good except in a few instances when temperatures were unusually low or when a strong breeze was blowing while the dusting was under way.

SUMMARY.—Experiments in the laboratory and in field plots demonstrated that

the pea weevil can be controlled in green peas and in dry peas by the application of derris dust mixtures with a rotenone content ranging from 0.5 to 1 per cent.

Large-scale field tests demonstrated that the application of dust mixtures containing either 0.75 or 1 per cent of rotenone derived from derris, cubé, or timbo, at rates ranging from 25 to 40 pounds per acre, gave satisfactory control. No significant difference could be detected between the performance of the two dilutions of the mixture. It was found that the use of a hood or of a short trailing canvas, on the dusting machine, increased the efficiency of the treatment by preventing excessive wind drift.

When the pea weevils continued to migrate from hibernation quarters to pea fields after the first dust application, two and sometimes three dustings were necessary.

Satisfactory control of the pea weevil was achieved only when all infested parts of pea fields were treated.—7-15-40.

LITERATURE CITED

Chamberlin, J. C., and K. W. Gray. 1938. Suggestions for the control of the pea weevil in Oregon with especial reference to peas grown for processing. Oreg. Agr. Expt. Sta. Cir. 126.

Larson, A. O., T. A. Brindley, and F. G. Hinman. 1938. Biology of the pea weevil in the Pacific Northwest with suggestions for its control on seed peas. U. S. Dept. Agr. Tech. Bul. 599.

Studies on the Biology and Control of Sod Webworms in California

RICHARD M. BOHART,[1] *University of California, Los Angeles*

The most serious annually recurring pests of bluegrass and bent grass lawns in California are larvae of the genus *Crambus* popularly known as sod webworms or lawn moths. When present in sufficient numbers these worms are capable of producing large brown areas in a lawn or may even kill it entirely. Their persistent attacks often lead to the replacement of the finer lawn grasses with coarser species or with some other type of ground cover.

In view of the various uncertain control methods in common use and the lack of information on the life history of the Californian species, a study of this problem was begun in the summer of 1938 and has been continued to the present time.

The two species of webworms known to damage lawns in California are *Crambus bonifatellus* (Hulst) and *C. sperryellus* Klots.[2]

DISTRIBUTION.—*Crambus bonifatellus* seems to prefer the more moist lowlands, and is especially common in the coastal counties from San Diego to San Francisco. *C. sperryellus* is the predominant form in dryer sections from Riverside and Los Angeles counties north through the San Joaquin and Sacramento valleys. Intermediate areas may harbor both species.

LIFE HISTORY.—The method employed in rearing involved the use of small stender dishes supplied with close-fitting bottom linings of blotter paper. Enough water was added to keep the blotter damp, and after cleaning the dishes freshly cut lengths of tender blue grass were supplied daily. As the two species concerned do not eat their cast head capsules, these were useful in keeping a record of the instars. The dishes were kept in the dark to more closely approximate natural conditions as well as to prevent the accumulation of moisture on the glass.

From experiments started in July, 1939, in rearing dishes, at laboratory temperatures of 65 to 80 degrees, with an abundance of food, it was found that the period from oviposition to emergence from the pupa was about 40 days. Moths from the same batch of eggs reared at outside temperatures ranging from 55 to 87 degrees emerged in about 45 days. Allowing a day or two for mating and first egg-laying, it can be seen that a complete life cycle would take roughly a month and a half during moderately warm weather.

The incubation period varies from 5 to

[1] The author has been materially aided in this study by R. H. Smith and R. J. Pence.

[2] Determinations by A. B. Klots.

10 days depending on the temperature. The oval reticulate eggs are laid dry without an adhesive and, after being deposited by the moth at rest or in flight, filter down toward the crowns of the grass. During incubation the eggs go through a color range of lemon yellow, clear bright orange, dark orange, and bluish. Eye spots become visible in the dark orange stage.

The larvae are slender active worms with the head and pronotal plate dark, the legs and caudal plate dusky grey, light to dark pinacular spots along the body, and a greyish to whitish body ground color. In the fourth instar the two species can be distinquished by a difference in markings which becomes more evident in later stages. In *Crambus sperryellus* dark spots on the head stand out in strong contrast to the yellowish background, the body ground color is whitish, and the body in general is more robust. In *C. bonifatellus* the head is more uniformly brownish, the body ground color is greyish, and the body in general is more slender. Six larval instars are normally present, and during periods of rapid growth the age of a larva can be approximately determined by its length. This is about one-eighth of an inch when a week old, three-eighths of an inch at two weeks, and after three weeks the full grown worms may be five-eighths to three-quarters of an inch in length. All stages have the habit of spinning silken shelters camouflaged with bits of grass and excrement. The first and second instar larvae work as skeletonizers of the grass blades whereas the later larvae cut notches in the edges of the blades or sever them completely. The greener portions of the crown are also subject to attack but, contrary to popular opinion, the grass roots themselves are not molested. This is indicated by the general observation that webworm frass is invariably a bright grass green. Additional evidence was obtained by confining half-grown larvae in a dish containing grass blades, crown, and roots. The grass blades were eaten at once followed by the greener portions of the crown but although fresh roots were supplied daily, no indication of feeding could be discerned even after several days' starvation.

Pupation takes place slightly below the surface of the ground in a loosely woven cocoon and the pupal period varies from 5 to 15 days, depending on the temperature.

The adults of the two species have strikingly different markings. *Crambus bonifatellus* has the forewing creamy buff with small and inconspicuous spots of white and brown or black, whereas *C. sperryellus* has the forewing golden with a longitudinal streak of silver.

Observations in 1938 and 1939 indicate the completion of four generations a year and the probability of a weak fifth when the summer weather is prolonged. Of these the second and third broods, which reach their peak in July and August respectively, are responsible for most of the damage recorded. Larvae of the fourth brood normally overwinter in silken shelters below the surface of the soil and emerge in April and May of the following year. Although the existence of four broods can be made out, there is so much overlapping that it is practically impossible to time control applications as recommended for eastern species.

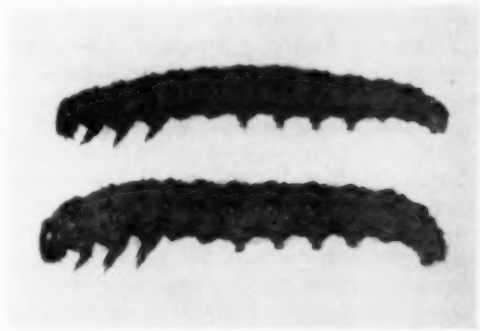


FIG. 1.—Mature larvae of *Crambus bonifatellus* (Hulst) (above) and *Crambus sperryellus* Klots (below), ×3.5.

Although a few internal parasites have been recorded, sod webworms seem to be singularly free from this type of natural control. However, an undetermined disease presumably of bacterial origin killed great numbers of worms early in the fall of both 1938 and 1939. Yellowjackets and blackbirds are the more important predators but seldom effect control.

DIAGNOSIS.—Damage by sod webworms is restricted mainly to bluegrass, *Poa pratensis*, or bent grass, *Agrostis palustris*, and a strong preference is shown for new lawns. Symptoms of infestation

are a general unthrifty appearance of the lawn in spite of watering and fertilization, followed by the appearance of rapidly widening brown spots. These spots may start in the middle of the lawn or at one side, but shaded sections are usually exempt. In badly infested spots definite signs of feeding marked by irregularities of grass height should be evident. It is not always easy to distinquish webworm damage from associated ills to which lawns are heir, but the actual presence of worms can be demonstrated by pouring a pyrethrum solution over the grass. A satisfactory testing solution is made by diluting one part of water-soluble pyrethrum extract containing about 2 per cent pyrethrins with 400 parts of water. If a gallon of this mixture is applied to the square yard, all but the smallest worms can be counted as they wriggle to the surface. In moderate infestations 50 to 100 worms can be counted to the square yard while heavy infestations may show as many as 750 worms in the same area.

As a rule, the pyrethrum test will also bring to the surface such associated insect pests as cutworms and skipper[3] larvae.

CONTROL.—Early work on the taxonomy and biology of the webworms in this country was done principally by Felt (1894) and C. H. Fernald (1896). For the most part their papers listed the species, gave keys, figures, short descriptions, and in some cases notes on habits, distribution, and food plants. However, the foundation for recent studies was made by G. G. Ainslie in a series of excellent papers published between 1918 and 1930, each of which treated a separate species of *Crambus*. Although Ainslie presented a careful study of bionomics, he gave no practical methods of control and it was left to later authors to propose the variety of control measures in use at the present time.

The status of control methods prior to 1930 is exemplified by a statement made by Ainslie (1930) in regard to *Crambus teterellus* Zincken that "No practical methods of control have been devised for this or any other species of *Crambus* larvae working in sod lands." According to Jewett (1939) he and W. A. Price succeeded in controlling sod webworms in lawns in 1930 and 1931 by means of a kerosene and soap emulsion. The use of either kerosene emulsion or a pyrethrum extract was recommended by Noble (1932). North & Thompson (1932) stated that a lead arsenate spray at 2 pounds to 1,000 square feet was a promising remedy. Pettit (1932) advised the use of pyrethrum estract, kerosene emulsion, or a soil treatment of lead arsenate at 5 pounds to 1,000 square feet. Campbell & Stone (1937) reported excellent control with a solution of dichloroethyl ether. A review of control methods is given by Jewett (1939) who recommends pyrethrum extract, kerosene emulsion, or a lead arsenate spray of 2.5 pounds to 1,000 square feet. The last named author made comparative tests of kerosene emulsion, a proprietary aliphatic thiocyanate, barium carbonate, nicotine oleate, lead arsenate, pyrethrum extract, derris powder, dichloroethyl ether, and cuprous cyanide. Of these only the three mentioned above gave staisfactory control. With the dichloroethyl ether only 31 to 74 per cent control was obtained when applied at the rate recommended by Campbell and Stone.

In 1938, 1939, and 1940 the writer made a series of experiments comparing acid lead arsenate, natural cryolite, pyrethrum extract containing 1.9 per cent pyrethrins, derris extract containing 2 per cent rotenone, dinitro-ortho-cyclohexylphenol, β, β_1 dichloroethyl ether, and two proprietary products containing dichloroethyl ether. Kerosene emulsion was not tried because the danger of injury from improper use and the difficulty of its preparation made it appear undesirable for use by the home owner.

All experiments were conducted in the field on infested lawns in the vicinity of Los Angeles. The general procedure was to mark off the lawn into sections of four square yards or more and roughly ascertain the number of worms present by applying to one-quarter square yard areas of each section the pyrethrum testing solution previously described. The lawn was then treated and after three days the pyrethrum check was repeated in different one-quarter square yard areas. This check was made once a week for several weeks in treated as well as untreated sections. In this way a fairly accurate picture was obtained of the effectiveness of each

[3] Lepidoptera, Hesperiidae.

insecticide from the standpoint of both immediate and prolonged kill compared with the normal fluctuation of population in untreated portions of the lawn.

Excellent temporary control approaching 100 per cent was achieved in a large number of trials through the use of lead arsenate at 5 pounds to the thousand square feet in 50 gallons of water, dichloroethyl ether diluted 1 to 400 in water at one gallon to the square yard, and pyrethrum or derris extract at the same dilution and quantity. A sprinkling can was used in all cases and the dichloroethyl ether solution was prepared by placing the proper amount in the bottom of the can and filling the can with a hard spray from a garden hose. This method also made a very satisfactory suspension of lead arsenate. Kills approximating 80 per cent were obtained by increasing the dilution of both the pyrethrum and dichloroethyl ether solutions to 1 to 800 and by using lead arsenate at 3 pounds to 1,000 square feet. With mixed populations of webworms it was found that the majority of surviviors after the last treatment were well grown specimens of *Crambus sperryellus*, indicating a differential in the resistance of the two species. A single test of cryolite at 5 pounds to 1,000 square feet gave a very good kill but severely burned a bluegrass lawn. Dinitro-o-cyclohexylphenol, 1 to 1,000 by weight in water, at one gallon to the square yard gave approximately 70 per cent kill in two tests.

Although the temporary results with sufficient strengths of lead arsenate, pyrethrum, derris, and dichloroethyl ether looked promising, subsequent weekly checks altered the picture. During July and August of 1939 and 1940 reinfestation and severe damage occurred in practically every case except where lead arsenate had been used. In most cases if the latter was used with an adhesive and allowed to dry thoroughly on the grass, no reinfestation took place even when untreated sections of the same lawn remained heavily infested throughout the season. In the author's opinion the majority of unsatisfactory reports on the effectiveness of lead arsenate in California can be laid to its use at insufficient strengths or to the method of application. As the worms feed on the crown and grass blades, the use of a soil mixture or of a dust which will quickly water down is obviously inefficient. In order to increase adhesive qualities 2 pounds of white flour was used by the author to every 5 pounds of lead arsenate and the mixture was allowed to dry thoroughly on the grass before watering. A light medium emulsive oil at 2 per cent was substituted in a number of cases for the flour but did not seem to be any more efficient and was more difficult to handle. Several instances have come to the attention of the author in which reinfestation apparently took place after the above recommended treatment of lead arsenate. In one case the insecticide was assiduously washed from the grass blades several days after treatment and a reinfestation became serious about a month later. The other cases occurred in those areas of Fresno and Riverside counties where excessive heat requires daily watering. Under such conditions two applications during the season of 10 pounds of lead arsenate and 4 pounds of flour may be necessary.

Occasional claims are made as to injury caused to sod by excessive amounts of lead arsenate. On the contrary, as previously stated by other authors, grass has a great tolerance for this insecticide. Although the tolerance varies with different species, no injury is anticipated from yearly applications at 5 pounds to 1,000 square feet where a normal amount of watering takes place. No injury to young seedlings of bent grass has been observed by the author from lead arsenate at the above strength on one month old lawns of bluegrass and bent grass, or on established lawns. In an attempt to demonstrate injury by excessive dosages, one flat each of year old Kentucky bluegrass and Washington bent were sprayed at weekly intervals, starting with acid lead arsenate and flour at the rate of 5 pounds and 2 pounds respectively to 1,000 square feet and increasing the strength each week until treatments were discontinued two months later. At this time the grass had received a total quantity of lead arsenate corresponding to nearly 1,000 pounds to 1,000 square feet. No definite injury could be discerned at any time by comparison with five untreated flats of each type of grass. Subsequently the treated flats exhibited a pronounced stimulation marked by thicker and more rapid growth. No

injury is evident at the time of writing, some seven months from the date of the last treatment. However, it is true that the flats in question were not subject to the packing effect of walking and mowing. It is common practice among greenskeepers to run a machine bearing sharp cutting blades over the greens to counteract the supposedly increased packing after repeated treatments with lead arsenate.

SUMMARY.—The two species of sod webworms known to damage lawns in California are *Crambus bonifatellus* and *C. sperryellus* Klots. The former occurs especially along the coast and the latter predominates in the dryer inland valleys. Bluegrass and bent grass lawns are favored. It was found that the California species can complete their cycle in six weeks or less in warm weather, and four generations are normally completed in a year.

Temporary control was obtained by the use of sprays containing pyrethrum extract, derris extract, and dichloroethyl ether, but none of these treatments prevented reinfestation in three weeks to a month's time. Therefore, it was necessary to repeat the treatment from one to three times during the summer. Lead arsenate used at the rate of 5 pounds to 1,000 square feet in 50 gallons of water with 2 pounds of white flour added as an adhesive gave excellent temporary control and retained its effectiveness throughout the season under most conditions. Where watering is done every day it may be necessary in some cases to make two applications a month apart using 10 pounds of lead arsenate and four pounds of flour to 1,000 square feet.—7-15-40.

LITERATURE CITED

Ainslie, George G. 1930. The blue grass webworm. U.S.D.A. Tech. Bul. **173**: 1–25.
Campbell, Roy E. and M. W. Stone. 1937. Dichloroethyl ether as a control for sod webworms in lawns. JOUR. ECON. ENT. **30**: 564.
Felt, E. P. 1894. Certain grass-eating insects. N. Y. Cornell Agr. Exp. Sta. Bul. **64**: 47–107.
Fernald, C. H. 1896. Crambidae of North America. Spec. Bul. Mass. Agr. Col.
Jewett, H. H. 1939. Control of sod webworms in lawns. Ky. Agr. Exp. Sta. Bul. **391**: 91–106.
Klots, A. B. 1940. North American *Crambus*. Part 1. The silvery-striped species of California. Bul. So. Calif. Acad. Sci. **39**: 53–70.
Noble, W. B. 1932. Sod webworms and their control in lawns and golf greens. U.S.D.A. Circ. **248**: 1–4.
North, H. F. and G. A. Thompson Jr. 1932. Investigations regarding bluegrass webworms in turf. JOUR. ECON. ENT. **26**: 1117–25.
Pettit, R. H. 1932. Insects infesting golf courses and lawns. Mich. State Agr. Col. Extension Bul. **125**: 1–11.

Females of the San Jose Scale Rendered Unproductive by Lime-Sulfur

M. A. YOTHERS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Many workers on the control of the San Jose scale, *Aspidiotus perniciosus* Comst. have found that some, and often a considerable proportion, of the overwintering scales survive various dormant sprays. Melander (1923), Ackerman (1923), Abbott *et al.* (1926), and Newcomer & Yothers (1931) reported that a number of these scales survived treatment with lime-sulfur.

Newcomer & Yothers (1929) in a preliminary note stated that many female scales which survived applications of lime-sulfur during the dormant period and grew to apparent maturity did not produce young, even though they remained alive through most of the following growing season. Pierce (1938) found that most of the females of the obscure scale, *Chrysomphalus obscurus* surviving applications of 2, 3, and 4 per cent oil-emulsion sprays failed to develop eggs and produce young. According to Pierce these results confirmed unpublished findings by Howard Baker.

Neither Pierce nor Newcomer & Yothers offer any explanation for this sterility of female scales. In the present paper a detailed record is given of observations and experiments which were conducted to throw light on the problem and which suggest an explanation of the failure of sprayed female scales to produce young.

Repeated examinations in 1925 and 1927 of females from trees sprayed with lime-sulfur showed that these females had not been fertilized or that they had been

in some way rendered sterile by action of the spray. Critical examination of the reproductive organs under the microscope revealed no deleterious effects of the spray. This lack of visible causes did not, however, mean that it could not have been the direct result of the action of the spray.

Dead scales soon lose their bright orange color and become dry and mealy. Repeated examination of the apparently live individuals showed them to be from bright orange to pale straw yellow, soft, pliable, and full of a transparent, watery fluid. Owing, in part at least, to the absence of young embryos within them, their general color was somewhat paler and more nearly transparent than that of bearing females. Their mouth parts continued their hold in the plant tissue. Fat globules and reproductive organs were present, and secreting glands were generally visible and in healthy, normal condition, secreting white waxy filaments posteriorly and dorsally.

In 1925 and 1927 and again in 1929 scales sprayed in March with lime-sulfur at 3 to 4 degrees Baumé survived in considerable numbers. The males surviving the longest developed to the adult winged stage but they all died about the middle of May without being able to emerge. Females, however, continued to live and develop throughout the season until as late as the middle of September, but none bore offspring. Throughout these years of observation no young were found within any of these surviving females and no young were produced.

LABORATORY AND FIELD TESTS.—In 1929 five principal tests were made; these are briefly summarized in the following paragraphs. Tests 1 to 4 were begun on May 16 and test 5 on May 17.

Test 1. To determine whether unfertilized females produce young and the longevity of unfertilized females, all dead and male scales were removed from a twig, leaving about 100 unfertilized females. This twig was confined in a celluloid cell plugged with cotton. Most of these unfertilized females were still alive on June 27, but none contained embryos, nor had they produced any young. The cage was accidentally broken open and the total longevity of these insects was not determined.

Test 2. Test 2 was conducted in a cell similar to that used in test 1, but both male and female scales were left in the cage as a check on normal conditions. The first young crawlers were observed on June 12. By June 20 they were observed in great numbers and by June 27 there were so many present that they gave the twig a grayish color. This cage was also broken open and the final results were lost.

Test 3. Test 3 was also similar to test 1. All males were removed in the pupal stage. Every few days up to July 6 from 10 to 20 females were removed and dissected under the microscope for embryos. None had produced young and none were found to contain young upon dissection.

Test 4. Scale-infested twigs that had been sprayed with lime-sulfur were placed in a jar with about an inch of water in the bottom to prevent drying. The jar was covered with cloth to prevent the escape of the males if any emerged. No males had emerged up to June 6, when the final examination was made, although emergence of normal male scales had occurred from May 15 to 22. All males had died, presumably from the effect of the lime-sulfur, before they could emerge, most of them while transforming from pupae to adults. About 7 per cent of the females were still alive on June 6, but none had borne young or contained embryos.

Test 5. All female scales were removed from an unsprayed scale-infested twig, just as males were beginning to emerge. This twig was then tied to a young pear tree close to sprayed scales, to allow emerging males to fertilize spray-surviving females. The twig was suspended in a jar of water to prevent drying, and left for several days. By June 27 the females had produced no young and contained no embryos. The males possibly did not find the females, or the females could not be fertilized, or the spray may have been repellent or lethal to the males.

Howard & Marlatt (1896) state that "It is very probable that many females have union with the males in the fall, but the majority of them are unquestionably immature, and are fertilized in this latitude (Washington, D. C.) early in April by overwintered males. . . . " According to the observations of the present writer, fertilization in the fall in the Pacific North west is probably rare, if it occurs at all, since females not fertilized in the spring, either as a result of the elimination of males by removal or by their having been

killed by sprays, were in all cases sterile.

These experiments indicate that the unproductivity of female San Jose scales sprayed with lime-sulfur may be due to the action of the spray on the generative organs or to lack of fertilization on account of death of the males by the spray. The opinion of the writer is that it is due to the latter, for the males are known to be more susceptible to spray action, all of them often being killed when a considerable proportion of the females survive.

In determining the control value of scalecides this factor of sterility of the surviving females should be taken into consideration. A survival of unproductive females, since they neither migrate nor reproduce, may be considered as of little consequence as far as injury or potential harmfulness is concerned. Final determination of the effect of a treatment should be made after eggs or young have had time to develop or at least to become distinguishable within the females.—7-15-40.

LITERATURE CITED

Abbott, W. S., J. J. Culver, and W. J. Morgan. 1926. Effectiveness against the San Jose scale of the dry substitutes for liquid lime-sulphur. U. S. Dept. Agr. Dept. Bul. **1371.**

Ackerman, A. J. 1923. Preliminary report on control of San Jose scale with lubricating-oil emulsions. U. S. Dept. Agr. Dept. Cir. **263.**

Howard, L. O., and C. L. Marlatt. 1896. The San Jose scale: Its occurrence in the United States, with a full account of its life history and the remedies to be used against it. U. S. Dept. Agr. Div. Ent. Bul. **3** (n.s.).

Melander, A. L. 1923. Tolerance of San Jose scale to sprays. Wash. Agr. Expt. Sta. Bull. **174.**

Newcomer, E. J. and M. A. Yothers. 1929. Sterility in the San Jose scale. JOUR. ECON. ENT. **22**(5): 821–2.

Newcomer, E. J., and M. A. Yothers. 1931. Experiments for the control of the San Jose scale with lubricating-oil emulsions in the Pacific Northwest. U. S. Dept. Agr. Cir. **175.**

Pierce, W. C. 1938. Control of the obscure scale on pecans with low concentrations of lubricating oil emulsions. JOUR. ECON. ENT. **31**(6): 722–4.

Further Notes on *Bathyplectes curculionis* and the Alfalfa Weevil in Lowland Middle California

A. E. MICHELBACHER, *University of California, Berkeley*

The influence of the larval parasite *Bathyplectes curculionis* (Thomson) upon the population of the alfalfa weevil, *Hypera postica*, in lowland middle California from the time the former was introduced in 1933 and 1934 through 1938 has been previously discussed. Michelbacher (1940). Since that time the investigation has been continued. In lowland middle California the alfalfa weevil is found in three areas having different climates. These are: The region adjacent to the San Francisco Bay, the agricultural area surrounding Pleasanton, and the northwest portion of the San Joaquin Valley. The regions are contiguous, but are separated from one another by ranges of hills, and the climate becomes more continental from the first to the last named region. It has been found that *B. curculionis* is most effective in the areas having the more moderate climates. In these climates the period of adult parasite activity is longer than in the more severe climate of the San Joaquin Valley. The parasitism trends in 1939 substantiated the findings of previous years, and are graphically shown in figure 1. The graphs were prepared in the manner reported by Michelbacher (1940). In the region adjacent to the San Francisco Bay and in that about Pleasanton the amount of parasitism was high and the alfalfa weevil population was small. In the northwest portion of the San Joaquin Valley the degree of parasitism was less and the alfalfa weevil population was considerable.

This investigation offered an unusual opportunity for study because both of the insects involved had been recently introduced into the areas under consideration. In most cases insects studied are already in a state of equilibrium with their environment, and frequently it is difficult to differentiate between physical and biotic effects upon the population. There can be no question but that the physical environment is very important in determining populations. However, in this regard Nicholson (1937) stated "While almost all factors in the physical and biotic environ-

ments of an animal may exercise some influence on its population density, competition is the only factor capable of regulating or governing populations." He goes on to show that the study of physical ecology cannot by itself give any information whatever about the actual population density of a species, but in order to know why a particular species has a certain abundance it is necessary to know how competition acts within the species. While an insect may usually be most abundant in regions where the physical environment is the most favorable, Nicholson shows that this need not always be the case. In lowland middle California observations made on the alfalfa weevil give evidence to support this contention. It certainly appears that the pest is most abundant in an area which, so far as the physical environment is concerned, is not the most favorable. The alfalfa weevil was found in lowland middle California in 1932. At that time it was found most abundant in the region about Pleasanton and the area adjacent to the San Francisco Bay. This condition existed until after *Bathyplectes curculionis* had been introduced into the infested area and had time to build up in population. After this occurred, the highest populations were found in the San Joaquin Valley, and especially at Pleasanton the population has decreased to a point where at most times any stage of the alfalfa weevil is difficult to find. The population has been so small that during recent years it has been nearly impossible to find enough alfalfa weevil larvae to conduct satisfactory parasitism studies. In order to demonstrate the changes that have occurred in the three different regions table 1 has been prepared. The largest number of larvae and adults collected to the 100 sweeps in each of the areas for each year is shown.

It would have been desirable to have had an opportunity to study the alfalfa weevil for several more years before *Bathyplectes* was introduced into the infested area. If this had been done a better measure of the normal variation in the density of the alfalfa weevil population in the absence of the parasite would have been obtained. However, all the evidence indicates that the greatest alfalfa weevil population density has shifted from a region having a more favorable physical environment to

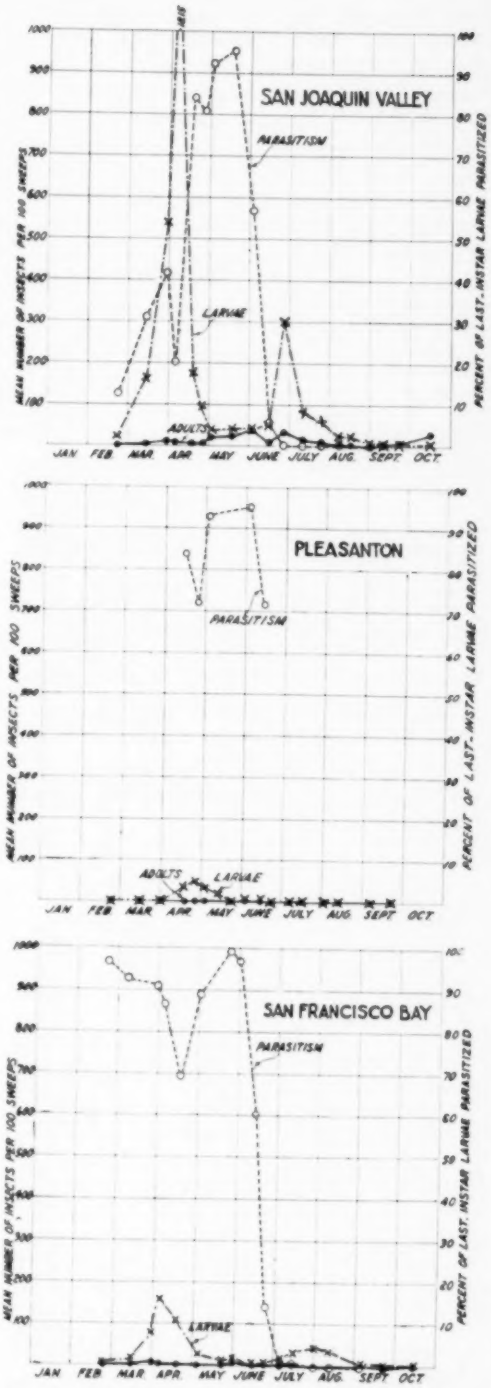

SAN JOAQUIN VALLEY
PARASITISM
LARVAE
ADULTS
MEAN NUMBER OF INSECTS PER 100 SWEEPS
PERCENT OF LAST-INSTAR LARVAE PARASITIZED
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT
PLEASANTON
PARASITISM
ADULTS
LARVAE
MEAN NUMBER OF INSECTS PER 100 SWEEPS
PERCENT OF LAST-INSTAR LARVAE PARASITIZED
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT
SAN FRANCISCO BAY
PARASITISM
LARVAE
MEAN NUMBER OF INSECTS PER 100 SWEEPS
PERCENT OF LAST-INSTAR LARVAE PARASITIZED
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT

FIG. 1.—Alfalfa weevil population and parasitism in the infested portion of lowland middle California, 1939: average number of larvae and adults collected per 100 sweeps of an insect net, and percentage of last-instar weevil larvae parasitized by *Bathyplectes curculionis*.

one having a less favorable physical environment. The reason for this unquestionably lies in the fact that the region that has the most favorable physical environment for the alfalfa weevil is relatively more favorable to *Bathyplectes* than is the physical environment of the San Joaquin Valley. In the former region *Bathyplectes* finds conditions so favorable to its development, and is so successful, that it is difficult for the alfalfa weevil to maintain any appreciable population.

Table 1.—Trend of the maximum populations of the Alfalfa Weevil, 1933 to 1939.

	Number of Weevils per 100 Sweeps of an Insect Net					
	San Francisco Bay Region		Pleasanton Region		Northwest portion San Joaquin Valley	
Year	Larvae	Adults	Larvae	Adults	Larvae	Adults
1933	1,762	128	6,482	205	642	93
1934	2,020	103	4,187	80	1,194	51
1935	1,444	77	727	103	1,672	47
1936	1,573	65	832	27	5,893	108
1937	434	4	332	8	2,072	151
1938	624	7	139	37	3,300	319
1939	158	10	90	4	6,038	141

Competition is so severe that the weevil population is reduced to a point where its density is considerably less than that found in a less favorable area. Had not an opportunity been afforded to study the weevil before *Bathyplectes* was introduced, it is very likely that the physical environment of the northwest portion of the San Joaquin Valley would have been thought to be more favorable to the pest than the more moderate climates nearer to San Francisco Bay.

In the more moderate climates it is possible that parasitism is so complete as to tend to obscure the spread of the weevil. During the spring of 1940 some evidence was obtained that indicates that this is the case. Since the alfalfa weevil was discovered in lowland middle California in 1932 but little extension of the infestation was observed in the coastal region south of San Francisco Bay. The climate of this region is one that is highly favorable to the pest and for that reason its failure to spread into this area created a puzzling problem. However, on surveys made on April 11 and May 2 the alfalfa weevil was taken in one locality outside of the known infested region. This was in a field about 1 mile south of San Jose. On April 11, two adult *Bathyplectes curculionis* were taken, and on May 2, one adult alfalfa weevil and 6 *Bathyplectes* were taken in 250 sweeps. On each survey a specimen of *Bathyplectes* was taken at the southmost point covered by survey, which was about 14 miles south of Hollister. If the finding of the parasite also indicates the presence of the alfalfa weevil, then the extension of the weevil infestation in the coastal area is increased in an air line distance by at least 60 miles. It would also mean that parasitism has been so effective that the spread of the alfalfa weevil went unnoticed. That the weevil occurs so far south must remain in doubt until specimens are actually collected. Nevertheless, the climate of the region is one that is known to favor nearly complete parasitism, and for that reason it would be possible to conduct a survey without picking up the alfalfa weevil. This conclusion is reached from the study of the alfalfa weevil about Pleasanton. In 1933 and 1934 as many as 500 to 6,000 larvae could be collected with 100 sweeps, while during the past season it was not uncommon to sweep as many as 3 or 4 fields without picking up a single specimen.

If the weevil actually exists as far south as the survey would indicate, then further light is thrown on the probable point at which the pest became established in lowland middle California. It is possible that it was established in the San Joaquin Valley, and spread into the cooler regions from there. In 1932, when it was first discovered, it probably had just recently spread into the region adjacent to San Francisco Bay, and had not had time to extend into the region south of that area. However, there was actually no barrier, and the weevil did extend its range, but as already stated went unnoticed because of the depredation caused by *Bathyplectes curculionis*.

The effect of *Bathyplectes curculionis* on the alfalfa weevil has been very remarkable. In the cooler regions it has greatly reduced the alfalfa weevil population. If conditions do not change considerably and *Bathyplectes* is in equilibrium with the environment, this will constitute an outstanding case of biological control. It is rather certain, though, that *Bathyplectes* has not come to an equilibrium with its new environment. This is suggested by the fact that from a large number of co-

coons collected in the alfalfa fields near Tracy on April 24, 1940, seven hyperparasites belonging to the genus *Eupteromalus*[1] were reared. What effect this secondary parasite will have upon the effectiveness of *Bathyplectes* remains to be seen.

SUMMARY.—In lowland middle California the larval parasite *Bathyplectes curculionis* (Thoms.) has had a marked effect upon the alfalfa weevil. It has been most effective in the cooler coastal regions where it has played an important part in reducing the alfalfa weevil population. Parasitism is much more complete than in the warmer more continental San Joaquin Valley. Because of the effective parasitism in the cooler region, the alfalfa weevil population is smaller than that found in the San Joaquin Valley, which is rather remarkable, for our investigation would indicate that the physical environment of the San Joaquin Valley is less suited to the alfalfa weevil than that which is found in the cooler coastal regions.—7-15-40.

[1] I am indebted to Mr. P. H. Timberlake for the identification of the parasite.

LITERATURE CITED

Michelbacher, A. E. 1940. Effect of *Bathyplectes curculionis* on the alfalfa-weevil population in lowland middle California. Hilgardia, **13**(3): 81–99.

Nicholson, A. J. 1937. The role of competition in determining animal populations. Australian Council Sci. and Indus. Res. Jour. **10**(2): 101–6.

Hydrocyanic Acid Dosages in Relation to Control by Fumigation of Red Scale *Aonidiella aurantii* (Mask.) on Citrus[1]

A. F. SWAIN and R. P. BUCKNER

For the past twenty-five years the problem of control of red scale, *Aonidiella aurantii* (Mask.) on citrus, particularly lemons, in California has been an increasingly difficult one. A major factor in this has, of couse, been the appearance and spread of the resistant strain of this insect, which now infests a considerable acreage in the State, generally the foothill districts of Los Angeles, Riverside, San Bernardino and Orange counties (Quayle 1938). Further factors influencing the increased severity of this problem are higher standards in packed fruit than formerly and lower incomes from fruit produced, causing lessened expenditures for control of the scale, which in turn results in heavier infestations. Continued research over this entire period since resistant red scale was first recognized greatly increased in the past decade, failed to solve the problem. In spite of all attempts to find more efficient insecticides, fumigation with hydrocyanic acid still remains the most satisfactory method of control of red scale.

Fortunately the resistant scale is no less susceptible to hydrocyanic acid fumigation than when first observed, but the area infested has been greatly extended (Quayle & Dickson).[2] Under conditions most favorable for scale growth and reproduction, fumigation once a year at the standard dosages of hydrocyanic acid has been insufficient to effect satisfactory control, or for that matter to prevent an increase in infestation. In some localities a fumigation every eight and even every six months has been necessary.

Under such conditions the question has arisen whether it is more economical to raise the dosage and with the resultant lower percentage of scale surviving to extend the time between fumigations, or to reduce the dosage and fumigate more often. In other words, the question is "What is the most economical dosage to use for the control of resistant red scale?"

If, starting with a small number, the population of an insect is plotted over time, a sigmoid curve is formed, subject, of course, to oscillations (Smith 1935). Such a curve indicates that population

[1] Contribution of the Entomological Laboratory of E. I. du Pont de Nemours & Co. Inc. The R. & H. Chemicals Department, El Monte, California, May 28, 1940.

[2] Unpublished manuscript.

growth at first tends toward a geometric increase, but as density becomes greater the rate of increase is reduced until finally an equilibrium is reached at which deaths equal births. This is what theoretically would occur where no control measures are practiced. However in a commercial citrus orchard the population of red scale cannot be permitted to reach a natural equilibrium or even approach that point,

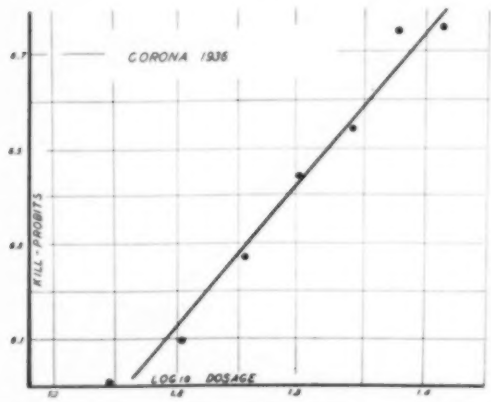


FIG. 1.—Dosage-Mortality curve, red scale fumigation, Corona 1935–36.

for the damage would be so serious that such an orchard would have passed out of commercial production. Since, therefore, in commercial orchards the condition represented by the upper portion of such a population curve is not permitted, it may be assumed that the population growth of red scale is geometric up to the point where an insecticidal treatment causes a sudden break downward in the curve. This means, briefly, that for any one period of time the rate of population increase is the same whether starting with one or more scales, as long as the populations are within the density range permissible in a commercial orchard.

FUMIGATION EXPERIMENTS.—During the fall and winter of 1935–36 a series of orchard fumigation experiments[3] was carried on in a lemon orchard in Corona, where in each row of trees six were fumigated at the 14 cc. dosage,[4] six at the 16 cc. and so forth up to and including the 26 cc. dosage. In all, 60 such rows were fumigated, totaling approximately 2,500 trees. Shortly thereafter mortality counts of mature red scale were made, the scale on fruits from every tree where infested fruits were present being counted. The results of these counts are shown in terms of probits plotted over the $\log_{10}$ of HCN dosage in figure 1. Using these findings the following calculations were made to determine a theoretical, most economical dosage. From this dosage mortality curve, expected percentages of surviving scale were calculated for dosages ranging from 10 cc. to 60 cc. per unit (Table 1, column 2). Assuming, as has been done, that population increase is a geometric function, it is evident where $\log_{10}$ of population density is plotted over time, that the time required for any number of scales less than any given number to increase to that given is a definite percentage of the time required for one scale to increase to that same given number. This is proved by the geometric theorem that a line parallel to one side of a triangle divides the other two sides into segments having equal ratios. The ratio of such time has been calculated (Table 1, column 3) for the expected per cent surviving scale for each dosage. Next, the cost of fumigating a tree at the various schedules was calculated using as a basis a tree requiring 16 units of HCN at 18 cents for coverage and 44 cents per pound for HCN (Table 1, column 4). Finally a cost-efficiency figure was obtained by dividing the cost of fumigation by the per cent of base time it requires the surviving scale to increase to the original population (Table 1, column 5 = column 4 divided by column 3).

Table 1.—Selected Cost Efficiency Data.

HCN Per Unit	Expected Surviving Scale	Base Time for Surviving Scale to Increase to Original Population	Cost to Fumigate a 16 Unit Tree	Cost Efficiency
10 cc.	30.020%	26.130%	28.88¢	1.105¢
20	7.570	56.045	39.76	.7094
30	2.400	80.990	50.64	.6253
40	.949	101.135	61.52	.6082
50	.415	119.100	72.40	.6079
60	.200	134.950	83.29	.6172

When the cost-efficiency factor is plotted over the $\log_{10}$ of the dosage (Fig. 2), it is seen that the low point is in the

[3] Appreciation of the excellent cooperation of D. A. Newcomb, Foothill Lemon Co., Corona, in the carrying out of these experiments is acknowledged by the writers.

[4] These refer to standard HCN dosage schedules that are in general use in California, and indicate the number of cubic centimeters of HCN per unit. The number of units per tree is determined by measurements of the tree and have been calculated on the basis of one unit per 100 cubic feet in medium sized trees, varying on larger and smaller as the ratio of volume to surface changes.

vicinity of 40 to 42 cc per unit. This low point in the curve will vary according to the relative costs of tent coverage and the unit price of hydrocyanic acid, but it indicates that dosages much higher than those in general use are the most economical. As previously stated, this is entirely theoretical and does not take into account the varying susceptibility of red scale to HCN at different seasons of the year and in different stages of development.

FIELD TESTS.—Following this study, field tests in various localities of Southern California were inaugurated in which portions of lemon groves were fumigated commercially at different dosages, principally 24 cc. (the maximum dosage in general use), and 28 cc., although in a few cases higher dosages were used. Prior to fumigation each tree in every test block was carefully inspected and given a numerical

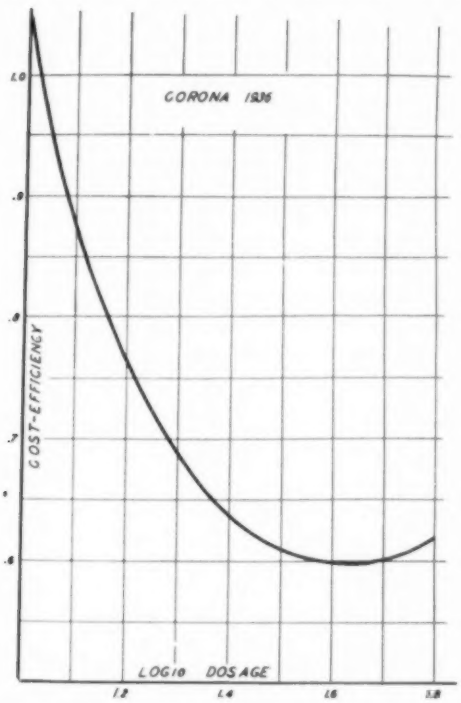


FIG. 2.—Fumigation cost-efficiency curve, based on dosage-mortality curve as shown in figure 1 and calculations in table 1.

value as to degree of infestation, such ratings ranging from zero (no scale found) to 4 (portions of the tree encrusted with scale and some branches killed). It was originally planned to make such ratings at periodical intervals after fumigation for a year or more, but in many cases it was not possible to carry this through because of such reasons as the necessity of controlling red mites, lack of complete cooperation by the grower, and so forth. However it was done in several cases, the results of which are discussed below.

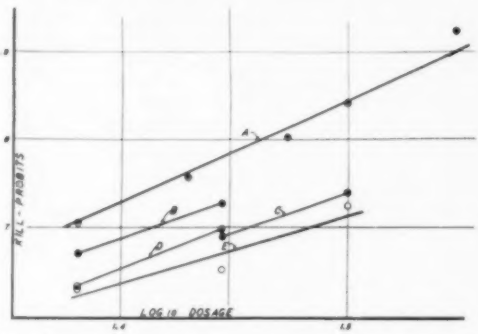


FIG. 3.—Dosage-mortality curve, red scale fumigation, miscellaneous orchards 1937–39.

Following fumigation, mortality counts were made and in all cases, as would be expected, a definite difference in scale kill was found between dosages. In Fig. 3 results from five such tests are shown graphically as per cent scale kill in terms of probits over the $\log_{10}$ of the dosage. It is quite interesting to note that the slopes of the dosage mortality curves are approximately parallel and that there is a wide range between the curves. This latter is to be expected for Curve A is based on the scale kill in a grove in Escondido infested with the normal strain of red scale, and Curve E is from a grove in East Whittier where the resistant strain of scale is prevalent, while in the other groves varying degrees of resistance are noted.

During the past three years data on prefumigation infestation and later infestation ratings have been obtained in five lemon groves.[5] The susceptibility of the scale to hydrocyanic acid vapors ranges from normal or non-resistant (Orchards A and I) to highly resistant (Orchard F). Table 2 gives the pertinent data on these experiments.

ORCHARD G.—In this orchard there

[5] The hearty cooperation of certain pest control operators, growers and others is acknowledged, especial thanks being due to Otto Baty of San Fernando, W. L. Worthy, Field Entomologist of the Los Angeles County Agricultural Commissioner's staff, and C. L. Holmes of Murphy Ranch Co., Whittier.

Table 2.—Summary of data—field fumigation experiments 1937–1939 inclusive.

Dosage HCN	Number of Trees	Dates of Inspection	Infestation Rating-Mean	Trees Practically Free from Scale (0+1)
Orchard G—Fumigated February 23, 1937				
24 cc.	80	Feb. 1937	1.57	60.0%
		Mar. 1938	0.85	77.5
28	80	Feb. 1937	1.41	52.5%
		Mar. 1938	0.54	92.5
L.S.D.[1]			.29	
Orchard H—Fumigated March 31, 1937				
24	60	Mar. 1937	2.61	25.0%
		Aug. 1937	1.03	71.7
28	60	Mar. 1937	2.38	23.3%
		Aug. 1937	0.17	96.7
L.S.D.[1]			0.40	
Orchard A—Fumigated January 6, 1938				
		Jan. 1938	3.91	0%
24	23	Dec. 1938	1.30	73.9
		Oct. 1939	1.52	52.2
		Jan. 1938	3.95	0%
27	21	Dec. 1938	1.10	90.5
		Oct. 1939	1.52	52.4
		Jan. 1938	4.00	—
30	8	Dec. 1938	1.00	—
		Oct. 1939	1.50	—
L.S.D.[1]			0.18	
Orchard F—Fumigated February 20, 1939				
24	72	Feb. 1939	1.96	47.2%
		Dec. 1939	2.53	22.2
28	72	Feb. 1939	2.21	26.4%
		Dec. 1939	2.33	20.8
L.S.D.[1]			0.34	
Orchard I—Fumigated March 3, 1939				
24	76	Mar. 1939	1.55	55.6%
		Dec. 1939	0.46	86.1
28	69	Mar. 1939	2.67	23.6%
		Dec. 1939	0.41	87.5
L.S.D.[1]			0.78	

[1] L.S.D. = least significant difference at the 5% point.

was a medium to light infestation at time of treatment and, as it is located where previous fumigation results would indicate the presence of some resistant scale, normal practice would consist of fumigation at the 20 cc. to 24 cc. dosages. Dosages of 24 cc. and 28 cc. both resulted in the infestation, a year after treatment, being distinctly less than at time of treatment, but the reduction from the use of the 28 cc. schedule was significantly greater than that from the 24 cc. schedule. This is shown not only by the infestation ratings, but also by the percentage of trees practically free from scale.

ORCHARD H.—For several years this orchard was fumigated at the 18 cc. schedule in the summer time, then standard practice in that locality, with the result that the scale infestation became heavier each year. Five months after this experimental fumigation the infestation where the 24 cc. schedule was used was only 40 per cent as heavy as at the time of treatment, but where the 28 cc. schedule was used it was only 7 per cent as heavy. Unfortunately from the standpoint of this experiment, the owner had the entire grove fumigated in September. The reason for this was not because of poor results, but because the results from these higher dosages were so satisfactory that the grower's faith in the efficiency of fumigation was revived and he desired to clean the grove thoroughly. Incidentally, the increase in amount of fruit free from scale from the first three picks in the summer of 1937 was sufficient to pay the entire fumigation bill.

ORCHARD A.—This orchard, located in Escondido, was so heavily infested with scale prior to the inauguration of this experiment that not only was there no fruit produced but a large proportion of the twigs and branches were dead. Three months after the fumigation the trees were scarcely recognizable as the same trees, due to new growth. A year after treatment they were so free from scale that no treatment was needed, and the difference between the 24 cc. plot and those where higher dosages were used was significant. Between the 27 cc. and 30 cc. dosage plots the difference was not significant, due partially to the small number of trees in the latter plot. By the following fall the infestations were approximately equal in all three plots, with the result that the entire block was fumigated in December 1939. Two years' control was obtained and although at the end of the first year there was a significant difference in favor of the higher dosages, this did not carry through for two years.

In the method of rating infestations, differences in lightly infested trees are difficult to enumerate, *i.e.*, grade 1 covers infestations where only one scale may be found to two or three fruit with a half dozen or more scales. Consequently, while average ratings between 1 and 2 may not show a significant difference statistically, actually they may be different.

From this test it would appear that with non-resistant red scale, although a dosage of 27 cc. to 30 cc. results in a lower infestation a year following treatment, 24 cc. was effective enough to reduce the scale population to such a low level that it was two years before noticeable numbers reappeared, and the higher dosage did not result in enough better control to permit delaying of treatment any longer. Commercial practice in this locality consists in the use of the 18 cc. to 20 cc. dosages, and is successful in keeping the scale under control for a year. It would have been interesting to include these lower dosages in this test, but the condition of the trees did not warrant it.

ORCHARD F.—This grove was quite heavily infested with resistant red scale and a year following fumigation it was found that where the 28 cc. schedule had been used the degree of infestation was the same as it had been at the time of treatment, but where the 24 cc. schedule had been used it had increased approximately 30 per cent. Neither the original nor the final infestations were significantly different between the two plots, but the increase in the 24 cc. plot was significant. At the time of treatment there were almost twice as many trees practically free from scale in the 24 cc. plot as in the 28 cc. plot, while a year later the percentages were the same.

ORCHARD I.—Results in this grove were in many ways similar to those in Orchard F, in that there was a distinctly heavier infestation prior to treatment in the 28 cc. plot than in the 24 cc. plot, but the following season the infestations were uniform throughout. Or in terms of trees practically free from scale, the percentage in the 24 cc. plot was more than twice as high as in the 28 cc. plot prior to fumigation, but the next winter they were the same. Results differed from the preceding, however, in that the infestation was materially reduced by both dosages, 70 per cent by the 24 cc. and 85 per cent by the 28 cc. dosages, whereas the higher dosage in Orchard F only prevented an increase in infestation. Apparently the scale population in this grove contains a much smaller percentage of resistant scale than in Orchard F. Although there is an apparent difference in the effectiveness over a period of a year between the 24 cc. and the 28 cc. dosages, it is quite possible that had this grove been left untreated another year, results similar to those observed in Orchard A would have been found. Actually a greater per cent reduction in degree of infestation was accomplished here than in Orchard A, so it would seem that insofar as commercial control is concerned, two years between treatments would have been entirely satisfactory. Unfortunately as the remainder of this grove was quite heavily infested this spring (1940), the grower included these experimental plots in the orchard treatment.

Incidentally, Orchards F and I are in the same district and are located only a couple of miles from each other. Resistant scale is relatively new in this district and apparently Orchard F is in the heart of that portion of the area where it first appeared. Orchards, F, G, and H all adjoin one another. When fumigated in 1937 results in Orchards G and H indicated an appreciable percentage of resistant scale, but definitely less than was present in 1939 in Orchard F. Orchard I, only two miles distant in the same general type of location, has not yet become infested with the resistant strain of red scale.

It would appear from these experiments carried on over a period of four years, that where the resistant strain of red scale is prevalent in lemon orchards, dosages of hydrocyanic acid higher than have been standard practice should be used. In these orchards it is quite apparent that an increase of one-sixth in amount of hydrocyanic acid used, which, on average sized trees, is about 10 to 12 per cent increase in cost of fumigation, has paid added returns. Where the resistant strain is only a small proportion of the population, or is absent, *i.e.*, where a fumigation at 24 cc. dosage holds the infestation under control for two years, the evidence does not show any added value for a dosage greater than that.

Observations during the past few years of commercial fumigation and of several tests where various dosages have been compared, verify the results shown in these experiments. As an example, in one grove (E in Fig. 2) a portion of which is on level land and a portion on a hillside with southern exposure, fumigated in December 1937, the 32 cc. dosage was used on the hillside and the 24 cc. on the flat or level ground. It is well known that scale reproduction is greater and development faster in locations such as the upper portion of this grove (Ebeling 1933) than in the flat below. Nevertheless in this case the lower portion required fumigation again in the fall of 1938, while the hillside was not fumigated again until the summer of 1939. In other words, fumigation at the 32 cc. schedule held the scale under control for six months longer than did fumigation at the 24 cc. dosage, in spite of the fact that the rate of increase was greater in the portion fumigated at the higher dosage.

In this entire discussion it must be borne in mind that fumigation of lemons for the control of resistant red scale is carried on mostly in the winter months (November to April) and all reference to the use of these higher dosages is based on the presumption that such fumigation will be carried on during that period. During late spring, summer and early fall, the use of such high dosages may result in injury to the trees or fruit and is not recommended.

In this connection, most of the pest control operators in the areas where the resistant scale is prevalent have, during the past two years, increased the dosages used to 26 cc. and 28 cc. on lemons. In the district where Orchards F, G, H and I are located, the present practice is to use the 28 cc. dosage where there is a relatively heavy infestation of scale and the 24 cc. schedule where lighter infestation occurs. The presumption is that either there is a greater percentage of the resistant strain present in the heavier populations or, due to favorable locations, the scale populations increase at a faster rate and hence require a higher per cent killed to keep them at a level low enough to prevent loss for a period of at least a year.

In the Arlington Heights and Corona districts of Riverside County, where the bulk of the fumigation of lemons during the past two seasons has been at the 28 cc. dosage, the general condition of scale infestations in the groves so fumigated is strikingly better than prior to the use of this high dosage.—7-15-40.

LITERATURE CITED

Ebeling, Walter. 1933. "Variation in the Population Density of the California Red Scale, *Aonidiella aurantii* (Mask.) in a Hilly Lemon Grove." JOUR. ECON. ENT. **26**(4): 851–4.

Quayle H. J. 1938. "Insects of Citrus and Other Subtropical Fruits," Comstock Publishing Co. 489–94.

Smith, Harry S. 1935. "The Role of Biotic Factors in the Determination of Population Densities," JOUR. ECON. ENT. **28**(6): 873–98.

A Method for Determination of Oil-Spray Residue on Citrus Foliage[1]

WALTER EBELING,[2,3] *University of California Citrus Experiment Station, Riverside*

A rapid and simplified method for the determination of the oil-depositing properties of oil sprays has recently been described (Ebeling 1940). This method involved the spraying of the upper surfaces of large citrus leaves by means of a laboratory precision sprayer, from a distance of 3.5 feet, the leaves being held in place against a metal plate by means of a steel spring clamp. The spray was applied at 450 pounds pressure, with a three sixty-fourth-inch disk in the nozzle. Each leaf was exposed to the spray for 5 seconds, and 50 leaves were sprayed in each test lot. After the leaves were sprayed, they were fastened to *Celotex* boards with thumbtacks and were dried for a period of 2 to 4 hours[4] in a cool basement with the aid of an electric fan. The portions of the leaves which had been held by the clamp during the spraying operation were then

[1] Paper no. 421, University of California Citrus Experiment Station, Riverside, California.

[2] Assistant Entomologist in the Experiment Station.

[3] The writer wishes to acknowledge the assistance of Lewis Wilson and R. D. Maine, of the Works Progress Administration.

[4] Since there are no stomata on the upper surface of the leaf, the amount of oil which penetrates the upper leaf surface in this period of time is negligible.

cut off, and the oil was removed from the remaining portions by washing with petroleum ether. After the washings were filtered, the ether was evaporated and the oil was weighed.

The method outlined has been modified as to the method of removing the oil from the leaves. After the petioles and portions of the leaves which are held by the clamp during the spraying operation have been cut off, the leaves are sandwiched between pieces of filter paper, which absorb the oil from the leaves when pressed in a vise. The leaves are placed in a press (Fig. 1), so that their upper surfaces, from which the oil is to be removed, face the

FIG. 1.—*A*, Press, in which citrus leaves are arranged with sheets of filter paper on top, to absorb the spray oil off the upper leaf surface, and with blotters beneath, to take up the irregularities in the lower leaf surface, such as midribs and veins. *B*, Frame, in which the press and its contents are held in place while leaves are being placed. (×0.18.)

filter paper, their lower surfaces facing a double thickness of blotting paper. The purpose of the blotting paper is partly to act as a cushion to receive the midrib and veins of the leaves, so that the sheets of filter paper on the upper surfaces of the leaves will be in contact with a smooth, uniform surface; and partly to absorb the small amount of oil which reach the under sides of the leaves while they are being pressed. Ten papers, 4 inches wide and $6\frac{2}{3}$ inches long, are sufficient to remove the oil from 40 leaves. Papers of these dimensions can be cut without waste from standard sheets of filter paper in 20-inch squares. If a greater amount of oil is deposited than is usual for citrus oil sprays (a condition which might obtain in laboratory work), two pieces of filter paper can be used together instead of one, in order that oil may not be lost by soaking through the filter paper and into the blotter on the other side of the leaves.

Papers and leaves are pressed in a vise (Fig. 2) for 1 minute. The oil is quickly ab-

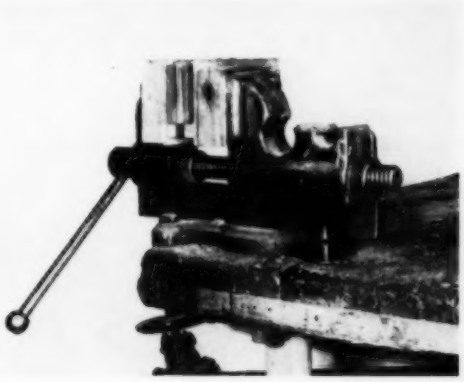


FIG. 2.—Leaf press in position in vise. The jaws of the vise are fitted with wooden frames to present a uniform surface to the leaf press and to hold the press in place as the vise is being operated. (×0.11.)

sorbed by the papers when they are under pressure and is then extracted by means of a "rubber extraction apparatus" (The Joint Rubber Insulation Committee 1917) which is a modified Soxhlet apparatus (Fig. 3). The sheets of filter paper are cut in half lengthwise, rolled into a tight roll, and inserted into the siphon cup. One hundred cubic centimeters of petroleum ether are used for the distillation, and the extraction process requires 1 hour.

After the extraction is complete, the ether is evaporated on the hot plate on which the distillation took place, until only about 10 cc. of oil and ether remain. This is transferred to a 50-cc. flask and increased to about 25 cc. with the ether used in rinsing. The 25 cc. of ether is evaporated by directing air from an airline, with which the laboratory table is supplied, into the flask for 30 minutes, while the

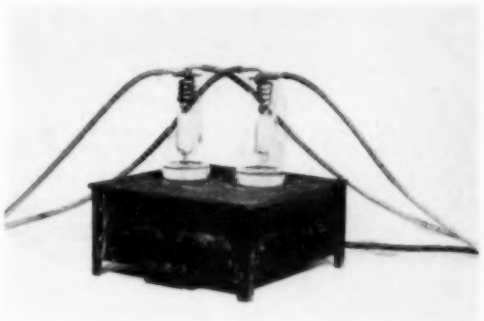


FIG. 3.—Extraction apparatus, with rolls of filter paper containing the oil absorbed from upper leaf surfaces inserted in the siphon cups and with 100 cubic centimeters of petroleum ether in the extraction flasks. (×0.10.)

flask stands in a water bath at 30 degrees C. (Fig. 4). The air escapes from the flask by means of furrows cut into the corks.

It was later found that if air is blown into open 50-cc. beakers containing the oil and ether, the evaporation can be just as

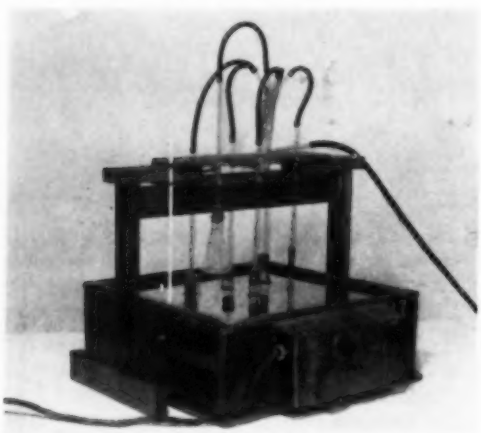


FIG. 4.—Apparatus for the evaporation of the petroleum ether from the spray oil. Air is blown into the flasks and escapes through furrows cut into the sides of the cork stoppers. The water bath in which flasks stand is kept at 30 degrees C. (×0.15.)

accurately done as by the use of flasks. This method has advantages, in that beakers are more easily cleaned and dried than flasks; also, since the evaporation is more rapid because of the larger surface involved, the water bath may be at the normal temperature of the tap water (about 20 degrees C.). The water prevents ether from forming frost on the beakers.

The oil remaining in the flask or beaker may be measured by gravimetric or volumetric methods. The gravimetric method is simpler and is used in preference to volumetric methods when the oils in question are sufficiently proximate in density so that relative weights will indicate relative volumes.

The oil remaining after the ether is evaporated has a whitish appearance when cool. This is caused by leaf wax which has been dissolved off the leaves by the oil. A small amount of leaf wax has a a great effect on the appearance and viscosity of the oil, as can be demonstrated by adding 1 or 2 per cent of a leaf wax, such as candelilla, to spray oil. The writer (Ebeling 1940) found that only 3.6 per cent of the oil removed from orange leaves by washing with petroleum ether 2 hours after spraying, was composed of sulfonatable waxes. Probably less wax would be contained in oil removed by the present blotter method.

DETERMINATION OF LEAF AREAS.—Leaf areas are determined by placing the leaves on large sheets of paper and covering them with a screen, then atomizing carbon tetrachloride, dyed with an oil-soluble dye, over the leaves. The carbon tetrachloride dries rapidly, leaving the imprints of the leaves which are to be measured, on the paper. Leaf areas are then determined by means of a planimeter Acetone may also be used as a spray in obtaining the leaf imprints, but carbon tetrachloride is better because it eliminates the fire hazard and penetrates paper less rapidly, thus making possible the utilization of both sides of the sheets of paper upon which the leaf imprints are made.

Table 1.—Percentages of error in processes involved in determination of oil-spray* residue on orange leaves.

Test No.	Percentage Error in Evaporation of Ether from Oil	Percentage Error in Extraction of Oil from Filter Papers	Percentage Error in Entire Process
1	+0.02	+1.9	+1.1
2	+0.07	+1.2	−2.6
3	+0.06	−0.2	+1.9
4	+0.11	+1.1	+1.2
5	−0.02	+1.2	+1.2
6	+0.02	+1.2	−1.1
7	+0.04	+0.7	+0.2
8	+0.03	+1.4	−0.7
9	+0.05	+0.8	+1.2
10	+0.04	+0.5	−0.4
Mean	+0.04±0.02	+0.99±0.18	+0.22±0.65

* A heavy-medium spray oil was used in these tests. The viscosity of this oil was 87 seconds; at 636 degrees F., 36 per cent distilled off; the unsulfonatable residue was 92 per cent. Between 300 and 400 milligrams of oil were used in each test.

RELIABILITY OF THE METHOD.—The method of oil-residue determination described in this paper is subject to error or variability from three sources: the evaporation of the ether from the oil after the extraction has taken place, the extraction of the oil from the filter papers, and the absorption of the oil from the leaves.

To determine the percentage of error in each process, between 300 and 400 milligrams of oil (the amount ordinarily deposited on 40 leaves, according to the methods of application used in the laboratory tests) was added to 25 cubic centi-

meters of ether, and the ether was evaporated by the method previously described. Likewise, between 300 and 400 milligrams of oil was smeared on 10 pieces of filter paper and extracted. Then equivalent amounts of oil were smeared on 40 orange leaves, blotted off, and extracted according to the method outlined in this paper. The mean percentage of error and the standard deviation, based on 10 tests, are shown in Table 1.

In all cases, the average recovery of oil was slightly greater than the amount of oil used in the experiment. This discrepancy is caused by non-volatile residues normally existing in petroleum ether and in the filter paper. The mean error of the entire process of extraction is less than that of the extraction from the papers alone, the former being 0.22 per cent and the latter, 0.99 per cent. The variability inherent in the entire process of extraction is greater, however, than that of the extraction from papers alone. This is shown by the relative standard deviations. Neither the mean error nor the variability of the process, is sufficient to be of practical importance.

Table 2.—Amount of oil deposited on citrus leaves by 2 per cent heavy-medium oil spray.

Test No.	Milligrams Oil Recovered from Upper Surfaces of 40 Leaves	Milligrams Oil Recovered from 1,000 Sq. Cm. Leaf Surface
1	379	119
2	367	120
3	394	126
4	346	116
5	357	120
6	344	117
7	344	111
8	350	120
9	377	119
10	384	122
Mean		119 ± 1.24

The amount of oil recovered and the variation per unit areas are shown in table 2. The differences between lots are larger than may be expected from errors inherent in the processes of oil removal and extraction (Table 1) and must therefore be caused largely by differences in the nature of the sprayed leaf surfaces of different lots of leaves. It is also possible that with different lots of spray, the volume of spray or the form of the spray stream may not be absolutely identical.

PRACTICAL QUESTIONS ANSWERED BY LABORATORY OIL-DEPOSIT TESTS.—In connection with the control of scale insects on citrus trees, the question whether increasing dosages of spray oil will result in correspondingly increasing amounts of oil deposit on the foliage, has often been asked. This problem was investigated in laboratory tests.

Table 3.—Effect of blood albumin spreader on the oil-depositing properties of oil spray.*

Test No.	Per Cent Oil Used in Spray	Milligrams Oil Recovered from 1,000 Sq. Cm. of Leaf Surface	
		Without Spreader	With Spreader
1	2	132	124
2	2	113	100
3	2	149	66
4	2	129	96
5	2	127	79
6	3	240	196
7	4	330	227

* Heavy-medium spray oil and blood albumin spreader at the rate of 4 ounces per 100 gallons of spray were used in these tests.

Forty citrus leaves were sprayed with 2 per cent heavy-medium oil spray used according to the tank-mixture method (Smith 1933) and containing blood albumin spreader at the rate of 4 ounces per 100 gallons of spray. The results of the oil-residue determinations are shown in figure 5. This figure shows that there is a straight-line relation between oil concentration in the spray and oil deposit on the foliage. Concentrations of oil above 2 per cent are not ordinarily used on citrus trees.

Figure 6 shows the straight-line relation between oil concentration in the spray and oil deposit on 40 citrus leaves, in other tests, sprayed with a heavy-medium oil used according to the tank-mixture method but with no spreader added to the spray.

The relative amounts of oil deposited by sprays used with and without spreader, as shown in figures 5 and 6, should not be construed as indicating the differences which would occur were the sprays used under identical conditions. In these tests, the form of the spray stream and the volume of spray had been changed in the period between the experiments.

Actually, the addition of blood albumin spreader at the rate ordinarily used in citrus spraying (4 ounces per 100 gallons of spray) decreases the oil deposit on citrus foliage for any given percentage of oil.

This is shown by the data in Table 3. The results of the various tests (Table 3) are not comparable, however, because the tests were made on different days and under different conditions, especially as regards the volume of spray and form of the spray stream.

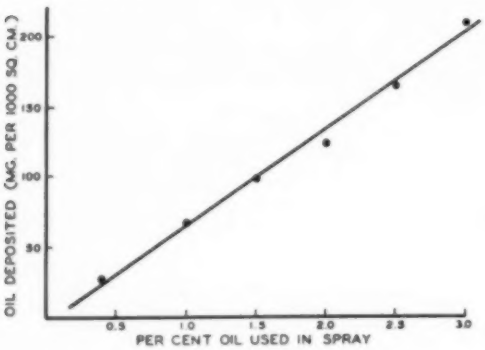


FIG. 5.—Relation of concentration of oil in spray to oil deposit on citrus leaves sprayed with a heavy-medium oil used according to the tank-mixture method, with 4 ounces of blood albumin spreader per 100 gallons of spray.

Blood albumin spreader at 4 ounces per 100 gallons of spray may increase the deposit of emulsive oils containing oil-soluble emulsifiers, which usually have a tendency to tighten the emulsion. In a number of tests, the writer found that when the oil-soluble emulsifier greatly reduces the deposit of oil below that which would be expected from the oil alone, blood albumin spreader may increase the deposit. The addition of blood albumin spreader also increases the deposit of oils which form tight emulsions because of their unsaturated hydrocarbons, that is, oils which have a low unsulfonatable residue. The deposit of 8 per cent smudge oil was increased from 59 to 162 milligrams per square centimeter by the addition of 4 ounces of blood albumin spreader per 100 gallons of spray.

Certain electrolytes, such as calcium chloride and aluminum sulfate, were found to be very effective in increasing the deposit not only of straight oil but also of various types of emulsive oils.

SUMMARY.—A method is described for the spraying of citrus leaves in the laboratory and the determination of oil-spray residue according to a simple and rapid technique involving the absorption of the oil off the upper surfaces of the leaves with filter paper and the subsequent extraction of the oil from the paper.

The oil concentration was found to have a straight-line relation to oil deposit. Blood albumin spreader, at the concentration at which it is ordinarily used (4 ounces per 100 gallons of spray), was found to decrease oil deposit on citrus leaves. Certain electrolytes were found to have the effect of increasing oil deposit.—7-15-40.

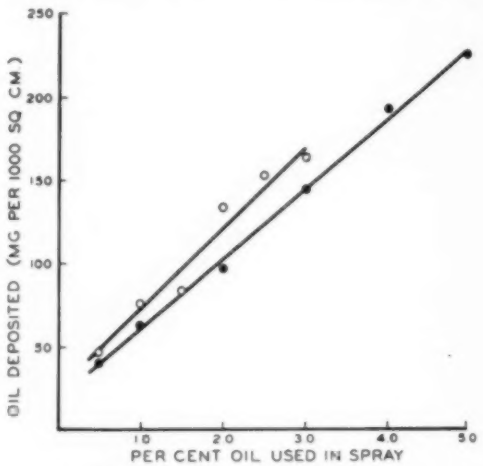


FIG. 6.—Relation of concentration of oil in spray to oil deposit on citrus leaves sprayed with a heavy-medium oil used without spreader or emulsifier. The two curves represent two separate experiments made on different days, with probably a slight difference in volume of spray.

LITERATURE CITED

Ben-Amotz, Y. and W. M. Hoskins. 1937. Factors concerned in the deposit of sprays. III. Effects of wetting and emulsifying powers of spreaders. JOUR. ECON. ENT. **30**(6): 879–86.

Ebeling, W. 1940. Toxicants and solids added to spray oil in control of California red scale. JOUR. ECON. ENT. **33**(1): 92–102.

Smith, Ralph H. 1933. The tank-mixture method of using oil spray. California Agr. Exp. Sta. Bul. **527**: 1–84. (Reprint.)

The Joint Rubber Insulation Committee. 1917. Report of The Joint Rubber Insulation Committee. Jour. Indus. and Engin. Chem. **9**(3): 310–7.

A Colorimetric Method for the Determination of Oil Deposit on Citrus Leaves[1]

G. L. McCall[2] and J. F. Kagy,[3] *University of California Citrus Experiment Station, Riverside*

The determination of the quantity of petroleum oil deposited on the leaves of a citrus tree by various spray emulsions has been the subject of considerable discussion and research. It is of primary importance to know the amount of oil deposited, in order to correlate the data with the factors of insect toxicity and injury to the tree. When oil sprays are tested to ascertain their respective toxicity to insects, it is very easy to draw erroneous conclusions with regard to differences in effectiveness. In reality, the apparent differences may be due to the fact that under a given set of conditions one spray emulsion will deposit a larger amount of oil than will another. A slight change in the physical or chemical properties of the emulsion may affect the results very markedly (Hensill & Hoskins 1935, Ben-Amotz & Hoskins 1937, Brown & Hoskins 1939). The accurate determination of the oil deposited is therefore of the greatest importance.

Various gravimetric methods for determining the amount of oil deposited on leaves by spray emulsions have been proposed. English (1930) described a method by which the oil was extracted from disks cut from the leaves, ether being used as the solvent. Dawsey & Haas (1933) modified this method. After the oil from the disks was extracted with ether, the solvent was evaporated to dryness, and the residue was redissolved in a mixture of ether and absolute alcohol. The leaf waxes were removed by precipitation at −30 degrees C., and the filtrate was treated with nitric acid in a Babcock skim-milk bottle. Swain & Green (1933) proposed a method whereby the oil was washed from the leaves with methylene chloride, the solvent was evaporated, and the residual oil weighed. The dissolved waxes were considered constant in weight and sufficiently small to be neglected. Tihenko & Hensill (1937) suggested a slightly different technique, in which there was no interference from plant waxes or essential oils. Citrus leaves were washed with acetone immediately after spraying, the water and solvent were removed by evaporation, and the soluble residue was dissolved in petroleum ether and filtered. The filtrate was then sulfonated and the amount of petroleum oil determined. Acetone, however, is a very inefficient solvent for oil, compared with the more non-polar compounds.

Consideration of various ways for determining the amount of oil deposited on citrus leaves led to the conclusion that a colorimetric method would be of value. Its advantages lie in the fact that it is rapid, very simple, accurate, and can be used over a wide range of oil deposits. In tests, an amount of petroleum oil as low as 19 milligrams from 25 leaves was determined by the use of this method. Small amounts of plant waxes and essential oils dissolved from the leaf by the solvent and present in the solution appear to have no effect on the color of the dye or the accuracy of the method.

Method and Materials.—The laboratory method used in these experiments was essentially as follows: A very small amount of a water-insoluble and oil-soluble dye, Sudan III, was dissolved in the petroleum oil, the depositing properties of which were to be determined. The upper surfaces of mature orange leaves were sprayed with the emulsified oil; the leaves were allowed to dry; and the deposited oil, containing the dye, was then washed from the leaves with an odorless kerosene. The resulting solution was filtered into a 50-cc. Nessler tube and made up to volume. This sample was then compared with standards of various concentrations prepared from the same dyed oil. The amount of oil present was determined as micrograms of oil per square centimeter of leaf surface.

A light-medium spray oil was used in all the determinations and was dyed as follows: Sudan III, which imparts a brilliant red color to the solution, was dissolved at the rate of 0.025 grams per 100 cubic centimeters of oil. The solution was then filtered to remove that dye which had failed to dissolve. (Filtration can be conducted rapidly in a large Buchner funnel with vacuum equipment.)

[1] Paper no. 420, University of California Citrus Experiment Station, Riverside, California.
[2] Associate in the Experiment Station.
[3] Research Fellow in the Experiment Station.

The solvent used for removing the deposited oil was the highly refined, colorless light distillate oil or "odorless kerosene" commonly employed as a base for household insecticides.

A sample of 25 mature orange leaves, approximately uniform in size, was selected. Each leaf was held flat against a metal surface by means of a steel spring clamp (Ebeling 1940), under which the petiole was placed, and was sprayed quantitatively, with the spray stream directed perpendicularly toward the exposed upper leaf surface. The leaf was then taken from beneath the clip by means of forceps and laid on a large sheet of paper, with the sprayed surface uppermost. The entire sample was treated in this manner. The leaves were allowed to dry for approximately two hours, after which they were ready to be washed.

The relative depositing properties of the emulsions may be ascertained by analyzing for the oil deposited on the upper surface of the leaf. Rohrbaugh (1934) showed that under certain conditions there was practically no oil penetration on the upper surface of an orange leaf for at least 24 hours, while penetration did take place on the lower surface. The amount of oil which penetrates the upper surface in from 2 to 4 hours is negligible (Ebeling 1938). Deposit determinations by several methods have indicated that it is almost impossible to extract all the oil from the leaves by any of the previously mentioned methods after it has once penetrated the leaf tissues. Because of these facts, no attempt was made to wash or extract any oil from the lower surface of the citrus leaf, and oil deposits were determined only on the upper leaf surface.

The deposited oil and dye were washed from the leaves with the aid of an atomizer, which proved efficient in removing the oil with only a small amount of the odorless kerosene. The solution of the dyed oil was filtered into a 50-cc. Nessler tube. As the affinity of the dye for filter paper is very small, residual dye which may be adsorbed by the paper is easily removed. The solution was then made up to volume, and its color was compared with a series of standards to ascertain the amount of oil washed from the leaves.

The choice of solvents was limited because of the fact that many solvents extract chlorophyll from the leaf and thus interfere with a colorimetric determination. Selection of an adequate solvent was made in the following way. Citrus leaves were placed in a given quantity of solvent, the containers were closed, and the leaves were allowed to macerate. After periods of 16 and 40 hours, samples were taken and compared for intensity of green color. It was found that the compounds which had little or no appreciable polarity appeared to extract the least chlorophyll. Petroleum ether, carbon tetrachloride, and a highly refined light-distillate oil or odorless kerosene were the only solvents tried which did not show the presence of appreciable quantities of chlorophyll after 40 hours. Petroleum ether, because of its volatility and the fire hazard, was not employed. Color standards of the dye in carbon tetrachloride faded appreciably on standing 24 hours; therefore this solvent was not considered satisfactory. Standard solutions of the dye in the odorless kerosene showed very little or no fading after 48 hours. This solvent satisfactorily removed the oil from the surface of the citrus leaves and was safe to employ. It was therefore decided to use this solvent for the colorimetric determination of oil.

Color standards were prepared as follows: Two grams of dyed oil were weighed, dissolved in the solvent, and made up to a liter. A series of known dilutions or standards of this stock solution were made in Nessler tubes, in order that the concentration of the unknown might fall within the desired range. Nessler tubes were employed in the determination because it was found that a standard colorimeter with a 50-mm. column was not sufficiently deep to offer enough contrast between the color of the unknown and the standard to achieve consistent results.

A series of 10 color standards, each containing from 20 to 40 milligrams of oil, was prepared. The strength of these solutions was increased in successive concentrations of 2 milligrams. Several individuals who had had little or no previous experience in colorimetric analysis succeeded in aligning the 10 standards in perfect order. Therefore, the maximum amount of reading error possible is 1 milligram in 20, or 5 per cent. This error markedly decreases as the amount of oil deposited on a sample of leaves is increased. If 100 mil-

ligrams of oil were deposited, the maximum reading error would be 1 per cent.

VALIDITY OF THE METHOD.—To establish the validity of the method used in these experiments, it was necessary to determine the percentage of oil which could be recovered from the surfaces of citrus leaves after a known amount had been applied. The following technique was used to ascertain the percentage recovery. A small beaker containing some dyed oil and a camel's-hair brush was weighed, and a small amount of the oil was spread evenly over the upper surfaces of citrus leaves. The amount of oil on the leaves was computed from the loss in weight of the beaker and its contents. The leaves were allowed to stand for a definite interval, after which they were washed and the amount of oil present was determined colorimetrically.

In Table 1, data are presented which show the recovery of oil from leaf samples which were allowed to stand for 2- and 4-hour periods after the oil was applied. The results of the determinations after the 2-hour period show that the mean percentage recovery of the oil was 98.62 with a standard error of 1.09 per cent. For a single determination, the standard error expected was 3.27 per cent. After a period of 4 hours, the mean percentage recovery was 98.21, with a standard error of 1.30 per cent, the standard error expected for a single sample being 3.44 per cent. Such variation is within the limits expected in colorimetric determinations.

Table 1.—Recovery of oil from citrus leaves at 2- and 4-hour periods after application.

Two-Hour Period*			Four-Hour Period†		
Milligrams Oil Applied	Milligrams Oil Recovered	Percentage Difference	Milligrams Oil Applied	Milligrams Oil Recovered	Percentage Difference
84.4	86.4	+2.37	51.4	50.4	−1.95
51.1	50.0	−2.15	54.0	53.0	−1.85
63.3	59.5	−6.00	58.2	53.6	−7.90
59.3	56.0	−5.56	57.8	57.0	−1.38
51.3	51.0	−0.58	48.9	49.2	+0.61
53.4	52.6	−1.50	46.8	47.0	+0.43
67.7	67.9	+0.03	59.2	59.0	−0.34
45.8	45.4	−0.87			
46.0	47.0	+2.17			

* Mean recovery of oil after 2-hour period, 98.62 per cent; coefficient of variation, 3.27 per cent.

† Mean recovery of oil after 4-hour period, 98.21 per cent; coefficient of variation, 3.44 per cent.

Of particular interest was a series of 24 laboratory oil-deposit determinations. The analyses were designed to obtain an estimate of the variation which can be expected in this method. The oil employed was a light-medium oil, emulsified by the tank-mixture method of Smith (1933), using blood albumin spreader at the rate of 4 ounces to 100 gallons. This type of emulsion is comparatively unstable and owing to its quick-breaking characteristics, has a tendency to build oil deposits. Because of these facts, more variation is expected with this type of emulsion than with many other types. Four different concentrations of oil were employed, and six replicate tests of each concentration were made. A summary of the oil-deposit data, expressed in micrograms per square centimeter of leaf surface, is presented in Table 2. Variability is expressed as the coefficient of variation (Snedecor 1938). These statistics are ratios of the standard deviation to the mean and are expressed in percentages. As might be expected, these values tend to vary inversely as the concentration of oil employed. The coefficient of variation for the entire experiment, computed by analysis of variance, was 5.38 per cent. This value is an average of the residual variation expressed in percentage of the general mean. Therefore, more than half the time, a deposit value should not be expected to vary from the mean by more than 5.38 per cent. The estimates of sample variation include the experimental error inherent in the method, together with any error introduced by the spraying procedure or by the determination of leaf area.

Table 2.—Summary and statistical analysis of data on oil deposit.*

Concentration of Oil, in Per Cent	Range Oil Deposited, in Micrograms Per Square Centimeter	Mean Weight Oil Deposited, in Micrograms Per Square Centimeter	Coefficient of Variation, Per Cent	Standard Error, Per Cent of Mean
0.5	28.37– 34.65	30.63	7.48	3.07
1.0	46.01– 53.98	50.73	6.21	2.55
1.5	79.31– 86.09	81.34	4.05	1.83
2.0	112.61–127.07	117.63	4.61	1.89

* Deposit data were obtained from samples of 25 leaves each (six replications), treated with a tank-mix emulsion.

The colorimetric method was devised primarily for the determination of oil deposits on citrus leaves in the laboratory, but it is not without its limitations. Certain colored toxicants dissolved in the oil could disrupt the method because of color interference. However, certain foreign materials, such as derris extractives, may

be incorporated with the oil mixtures if these materials are also introduced into the color standards at the same concentration at which they are used in the spray oil. It is highly improbable that the presence of small amounts of Sudan III will appreciably alter the properties of the oil.

The method can also be adapted for certain types of field experiments. Because of the rate of penetration of oil into the leaves, it would be desirable to have the washing procedure conducted in the field within 2 hours after the trees are sprayed. The task of preparing large amounts of the dyed oil for field usage might become laborious, and certain commercial paste emulsions would require special preparation; but in most instances, the method may be used in the field to advantage.

SUMMARY.—A colorimetric method for the determination of oil deposited on citrus leaves by spray oil has been described. The method is rapid, simple, and accurate and can be used over a wide range of oil concentrations.

The method consists in the staining of the spray oil with Sudan III. After the dyed oil has been sprayed as an emulsion, the deposited oil is washed from the leaves with a highly refined light distillate oil or odorless kerosene, found to be a satisfactory solvent for removing the spray oil from the upper surface of citrus leaves. The amount of oil deposited is determined by comparing the color intensity of the unknowns with a set of color standards prepared from the dyed spray oil in question.

The recovery of oil from leaves by the use of the colorimetric method averages 98.41 per cent, and the laboratory oil-deposit determinations show an average coefficient of variation of 5.38 per cent. The standard error, in per cent of the mean, varies from 1.83 to 3.07 per cent. An amount of oil as low as 19 milligrams was determined from a sample of 25 leaves. Plant waxes and essential oils do not appear to affect the accuracy of the method.*

—7-15-40.

* ACKNOWLEDGMENTS.—The writers wish to express their appreciation for the valuable suggestions of L. E. Mills of the Technical Research Department of The Dow Chemical Company and for the aid received from R. L. Beier and A. M. Boyce of the Citrus Experiment Station.

LITERATURE CITED

Ben-Amotz, Y., and W. M. Hoskins. 1937. Factors concerned in the deposit of sprays. III. Effects of wetting and emulsifying powers of spreaders. JOUR. ECON. ENT. **30**(6): 879–86.

Brown, G. T., and W. M. Hoskins. 1939. Factors concerned in the deposit of sprays. V. The effects of pH upon the deposit of the oil and water phases of oil emulsions. JOUR. ECON. ENT. **32**(1): 57–61

Dawsey, Lynn H., and A. J. Haas, Jr. 1933. A method for determining the quantity of mineral oil retained by leaf surfaces after spraying. Jour. Agr. Research **46**(1): 41–9.

Ebeling, Walter. 1938. Penetration of spray liquids into plant tissue. Verh. VII. Internatl. Kong. f. Ent. Band IV: 2966–82.

Ebeling, Walter. 1940. Toxicants and solids added to spray oil in control of California red scale. JOUR. ECON. ENT. **33**(1): 92–102.

English, L. L. 1930. A method for determining the quantity of oil retained by citrus foliage after spraying. Jour. Agr. Research **41**(2): 131–3.

Hensill, G. S., and W. M. Hoskins. 1935. Factors concerned in the deposit of sprays. I. The effect of different concentrations of wetting agents. JOUR. ECON. ENT. **28**(6): 942–50.

Rohrbaugh, P. W. 1934. Penetration and accumulation of petroleum spray oils in the leaves, twigs, and fruit of citrus trees. Plant Physiol. **9**(4): 699–730.

Snedecor, G. W. 1938. Statistical Methods. Revised ed. Collegiate Press, Inc., Ames, Iowa.

Smith, Ralph H. 1933. The tank-mixture method of using oil spray. California Agr. Exp. Sta. Bul. **527**: 1–84. (Reprint.)

Swain, A. F., and Don Green. 1933. Detection and determination of surface oil on citrus following spraying. [Abstract.] JOUR. ECON. ENT. **26**(6): 1021–30.

Tihenko, V. J., and G. S. Hensill. 1937. Method for determining amount of mineral oil deposited on orange leaves immediately after spraying. JOUR. ECON. ENT. **30**(2): 355–60.

RESTRICTIONS on the movement of fruits and vegetables under the Japanese bettle quarantine were removed for the season effective September 19, 1940, the active period of the beetle in its relation to fruits and vegetables having ceased by that date. The order released these products from the certification requirement nearly four weeks earlier than is provided in the regulations.

HAVING determined that the sweetpotato weevil does not exist in that part of George County, Miss., lying east of the Pascagoula River, the Alabama Department of Agriculture and Industries amended the sweetpotato weevil quarantine effective October 23, 1940, to apply only to that part of the county lying west of the river.

The Present Status of Organic Insecticides for Codling Moth Control[1]

R. L. Webster, James Marshall and Herman Fallscheer

The argument for organic insecticides to combat the codling moth is based on the assumption that such insecticides may be used continuously throughout the growing season to check the entering worms, that the material used will retain a high degree of efficiency up to harvest, and yet may be sufficiently dissipated at the time fruit is picked so that no dangerous residue is left on the fruit. This is indeed a large order.

It is not to be expected that the entire necessity for washing fruit may be avoided, although on occasion growers have been able to meet requirements following a program of wiping. It has been anticipated that washing to remove visible residue following a series of cover sprays with an organic material may be entirely feasible. Three essentials are particularly important: adequate worm control, easy residue removal, and low cost.

In selecting organic materials as insecticides we must always remember that poisons are poisons and that any material that may be used to control insects is likely at the same time to be poisonous to human beings. On the other hand there is evidence which indicates that certain of these materials are less toxic to higher vertebrate animals than others. A search for efficient material for codling moth control has been in the direction of utilizing materials much less dangerous to mankind, although at the same time representing a high degree of efficiency against the insect. There always remains the possibility, however, that new insecticides may be developed to a high degree of efficiency in order to meet a particular problem, only to find out that these materials may be considered as deleterious by the Food and Drug Administration. This has happened before and may happen again.

Nicotine Combinations.—Several years ago two of us made a summary of this problem so far as the use of nicotine is concerned, with particular reference to conditions in the Pacific Northwest (Webster & Marshall 1934). Since that time some attention has been paid to the use of organic materials in the experimental orchard at the Tree Fruit Branch Experiment Station at Wenatcheee, under the immediate supervision of the authors. Some of these trials were preliminary and not particularly encouraging. Others were made under more carefully controlled conditions and in consequence results are more dependable. The investigations included trials with nicotine compounds, pyrethrum extracts, phenothiazine, and xanthone. These investigations are briefly summarized herein and include experimental data covering the period from 1932 to 1939 inclusive.

Because of the wide use of nicotine as an insecticide more emphasis was placed on its use experimentally since there were greater hopes that nicotine in some form might prove a feasible substitute for lead arsenate. Early attempts to utilize nicotine were directed to substitution of nicotine combinations with mineral oil late in the season, but the use of oil at ovicidal concentrations generally was followed by greater difficulty in residue removal—the very difficulty to be avoided.

Nicotine-Oil.—A nicotine spray schedule was followed throughout the season at Monitor in 1935 and 12 Rome trees were sprayed with a nicotine-oil combination. In this case a nicotine extract known as "Nicotinum," was used, said to contain 9 per cent alkaloid nicotine and manufactured by the American Nicotine Company, Henderson, Kentucky. The material was said to represent a complete extract of the tobacco plant.

Six cover sprays were applied, using one quart of the extract to 100 gallons of water with two quarts of a 70 viscosity oil. The last cover was applied August 12. Because of many late worm entries the amount of wormy fruit was high, 52.5 per cent while the lead arsenate-herring oil check ran 42.3 per cent wormy fruit. While it was felt that a greater number of applications might have definitely improved control, the results did not justify any expansion of our experimental program in this direction.

[1] Published as Scientific Paper No. 464, College of Agriculture and Agricultural Experiment Station, State College of Washington.

Again at the experimental orchard in 1938 a combination of nicotine sulphate and light-medium oil was applied throughout the season in a demonstration block of Romes. In this case the calyx and first cover sprays consisted of calcium arsenate, to which was added zinc sulfate and lime and a casein spreader. Cover sprays 2 to 9 were composed of two-thirds pint nicotine plus one-half gallon of a 60-65 viscosity oil. Cover sprays were applied May 31, June 7, 21, July 5, 18, 30, August 8 and August 20. Forty to 45 gallons of spray per tree were used at each application. At harvest there was 63 per cent wormy fruit; not a very creditable showing for the block. Experience of this kind substantiates our attitude in recent years that the nicotine-oil combination is not effective in a severely infested orchard. A near-by block of Romes, sprayed with a modified "Dynamite" combination, had 48 per cent wormy fruit at harvest.

NICOTINE-MOLASSES FIASCO.—Our own work had been accomplished under conditions of severe infestation. Occasional growers in isolated locations and with light infestations continued to use nicotine in one form or another. Reported success with a nicotine-molasses combination were current in the Wenatchee Valley during the winter of 1937–1938, and it soon became evident that many growers, especially those who had encountered difficulty in washing their fruit, would attempt to use such a combination in order to avoid lead residue. No direct experimental evidence was available on the value of this combination but this did not check the unwise publicity over the new spray treatment. Six cover sprays of nicotine sulfate with "*Karo*" corn syrup had been applied by Spuler in 1929, but its use resulted in severe markings on the fruit.

In formulating spray recommendations for Washington for 1938, the following statement was made concerning this combination. "The value of the nicotine sulfate-molasses mixture has not been established, and it may be dangerous." Notwithstanding this warning many fruit growers plunged headlong into the use of this material, and 61,659 pounds of nicotine sulfate were used in district No. 4, which includes Chelan county and parts of Douglas and Grant counties, in 1938. According to records furnished by the State Department of Agriculture, 21,781 pounds of nicotine were used during the 1937 season in district No. 4. The previous high mark had been 38,328 pounds in 1933, following the imposition of a tolerance on lead for the first time.

The results were disastrous. It was the last straw for many a grower, already in a difficult position because of high costs and low prices. Wormy fruit in orchards was so evident that the use of the nicotine-molasses combination was abandoned completely the following year.

Because of constant requests for information on the value of this combination a block of Romes was sprayed with the "nicotine-glucide" combination in 1938, using one gallon to 100 gallons of water for eight cover sprays. After two cover sprays there was a deposit of .053 microgram per square centimeter. One day after the fourth cover spray this was 0.58 microgram. Three days after the fifth cover spray the nicotine amounted to 1.3 micrograms per square centimeter. This is equivalent to approximately 8.4 micrograms per square inch, a quantity far short of that really necessary, according to later investigations. Out of 1,404 fruits counted 87 per cent were wormy. Had this information been available the year before thousands of dollars might have been saved the industry, although it is always difficult to determine trends in the use of new and untried materials by growers already desperate because of low prices and advancing production costs.

NICOTINE-BENTONITE.—Promising results had been obtained with a nicotine-bentonite combination in 1938, and during 1939 an effort was made to determine more definitely the quantity of nicotine necessary to attain control in a severely infected orchard. Analyses were made before and after cover sprays in order to determine the quantity necessary to bring about control. In one plot nicotine was used at the full concentration, *i.e.*, one pint of nicotine sulfate to each one hundred gallons of water, to which was added five pounds of bentonite and one quart of herring oil. Eight cover sprays were applied, but in the last two cover sprays the nicotine-oil combination was substituted for the nicotine-bentonite because it was felt that the fruit would not brush clean with so great a quantity of bentonite residue. These tests were on Jonathans.

Because of the high cost of the full con-

centration of nicotine a companion plot was sprayed with one-half pint of nicotine sulphate (with $2\frac{1}{2}$ pounds of bentonite, 1 pint herring oil, to 100 gallons of water). This was applied in the third, fourth, fifth, and sixth cover sprays, being followed with two additional sprays in which nicotine-oil was used, in order to make a more accurate comparison with the previous named plot. At harvest it was very evident that the quantity of nicotine could not be cut down to this extent without sacrificing control. In fact, the wormy apples were more than doubled where only one-half pint of nicotine sulfate was used, 52 per cent on this block compared to 21.2 per cent where the full concentration was used. Extra fancy apples on the plot where one pint was used were 38.3 per cent, where one-half pint was used there were only 23.4 per cent extra fancy.

From the chemical data it was apparent that protection was not obtained where the quantity of nicotine fell below about 34 micrograms per square inch, a minimum which was reached previous to the seventh cover spray. While this figure represents a minimum, the maximum protection on this plot was between 88 and 100 micrograms, according to our analyses. Where "*Black Leaf-155*" was used, the protection in terms of micrograms per square inch was even lower, and there was a corresponding lack of protection from worms and stings.

PYRETHRUM EXTRACTS.—Nearly every year there has been included in the experimental program at Wenatchee, at least on a few trees, some combination of a pyrethrum extract. In general the results have been so disappointing that they were not followed up by similar trials and more detailed experiments in succeeding years. In 1932 the application of an oil-pyrethrum combination in the fifth and sixth cover sprays following lead arsenate, resulted in 31.8 per cent wormy fruit, as compared to 15.0 per cent on the control plot (lead arsenate 3–100). Where the oil-pyrethrum combination was substituted in cover sprays one, two, five, and six, there was 21.8 per cent wormy fruit, the difference possibly due to the ovicidal effect of the oil when applied in the early cover sprays.

In 1934 pyrethrum was used in a variety of ways with most unsatisfactory results. Continued applications throughout the season failed to accomplish any degree or control. Our records show that pyrethrum was used as the acetone-alcohol extract (1 per cent pyrethrins), as a pine oil extract (2 per cent pyrethrins), and ground pyrethrum flowers at equivalent concentrations of pyrethrins.

Again in 1935 a commercial product, said to have been used with success in the New England States and evidently a combination of pyrethrins and oil, was applied on Stayman Winesap trees in seven cover sprays, three-fourths gallon per 100 in all the cover sprays except the fourth, where for some reason the concentration was one-half gallon. The last cover spray was applied August 17. In this case there were 35.7 per cent wormy apples as compared to 8.9 per cent wormy in the control trees. Experience of this nature year after year naturally results in a lack of enthusiasm on the part of the investigator and a subsequent tendency to place more emphasis on materials that appear more effective.

PHENOTHIAZINE.—Comparatively little work has been accomplished with phenothiazine in our experimental program. In 1936 we attempted to find out whether this material could be used at a concentration as low as 1 pound to 100 gallons of water, but this quantity was too low. 37.3 per cent wormy apples resulted in this test, which was compared to a control near by in which 25.6 per cent fruit was wormy. While later applications at the rate of 2 pounds to 100 gallons were used, the worm entry during the first brood had been so great that stepping up the concentration was not sufficient to hold the worms.

Again in 1939 phenothiazine was used on Jonathans with stove oil in a limited way throughout the season. In one case there was 46 per cent wormy fruit, the other 54 per cent. Infestation in this portion of the orchard was heavy.

"GENICIDE."—For several years the General Chemical Company has been doing some experimental work with an organic compound, now called "*Genicide*," with considerable success. Last year at the demonstration plots at Wenatchee a block of Jonathans and a block of Delicious were sprayed with this material with unusually good results. The active insecticidal agent in "*Genicide*" is a diphenylene ketone oxide known as xanthone.

"*Genicide*" was used in eight cover

sprays at the rate of 2 pounds per 100 gallons of water, to which was added one pound of "*Grandpa's Tar Soap*" and three-fourths pound hydrated lime. In the Jonathans 16.8 per cent of the fruit was wormy, on the Delicious 11.5 per cent. These investigations were preliminary, not included in our regular plots, and no adequate check was available. On a block of trees not far distant, however, sprayed with lead arsenate and oil during the early covers, followed by four covers of cryolite, there was 47.6 per cent wormy fruit, indicating a high degree of control on the part of "*Genicide*."

Trials of "*Genicide*" on the two tree plots, where it was used with stove oil, indicated results even more favorable. In one case there was 9.4 per cent wormy fruit, the other 9.9 per cent in a heavily infested portion of the experimental orchard.

SUMMARY.—While most of our activities with organic insecticides for codling moth control have been concerned with the use of nicotine, it is quite apparent that under conditions of severe infestation such as prevail in central Washington, it is necessary to maintain an unusually high degree of protection throughout the season in terms of micrograms nicotine per square inch of apple surface. This leads to unusually high costs which are not compensated by freedom from residue removal. A high degree of efficiency may be obtained, however, lead residue may be eliminated, and comparative freedom from foliage and fruit injury avoided by the use of nicotine.

Application of various pyrethrum extracts, usually combined with mineral oil, has not been encouraging.

The use of phenothiazine has so far not been very encouraging, according to our experimental data. Xanthone, in the form of "*Genicide*," has given much better results.—7-15-40.

LITERATURE CITED

Webster, R. L., and James Marshall. 1934. The Position of Nicotine in Codling Moth Control. JOUR. ECON. ENT. **27**: 873–8.

An Improved Method of Applying Insecticidal Dusts

A. G. GALLOWAY and A. F. BURGESS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

This paper describes a method of dispersing insecticidal, or fungicidal, dusts, with liquid adhesives, so that a uniform, controlled dispersion rate may be maintained under varied conditions, and adherence of the finely divided particles of insecticides to foliage may be obtained.[1] The principle involved in this method is such that the process may be used in conjunction with aircraft in combating insects or plant diseases, or it may be adapted for use with relatively slow moving ground equipment of the type generally used in the treatment of truck and orchard crops.

Investigational work on gypsy moth control at Greenfield, Mass., has for several years included the development of equipment and methods for applying insecticides more effectively and economically in extensive and difficulty accessible woodland areas. Particular attention has been given to the study of possible uses of aircraft in this connection. The results of this study indicated that the autogiro was the most promising type of aircraft, in view of its ability for slow, controllable flight and its safe operation over terrain where the use of the fixed-wing type of machine would be dangerous.

Tests were made with different types of distributing equipment, the construction of which would permit satisfactory attachment to autogiros of current design. These tests were begun in 1936 and extended over a period of more than a year. They were conducted in a specially constructed room, which was in effect a wind tunnel. In this chamber high-velocity air movements were created by means of suitable fans, under conditions as nearly comparable as possible with those encountered by aircraft in flight. Dispersing units of various designs were constructed and studied in the distribution of dry, semiliquid and liquid insecticides. Both wind- and power-driven types of appara-

[1] U. S. Patent No. 2,172,001, issued September 5, 1939.

tus were tested, and special attention was directed toward the design of equipment which would give the most satisfactory distribution under all conditions encountered in applying insecticides to forested areas with rotating-wing aircraft.

Wind-driven devices in general appeared to be incapable of uniformly measuring and distributing materials, particularly those in a semiliquid state. The relatively large quantities of material that must be released in a unit time, plus the density of this material as compared with that of the propelling medium, air, necessitated power requirements which could not be met in equipment of practical design. In addition, wind-driven apparatus were found to be so subject to variations in speed that they could not be relied upon to uniformly dispense measured quantities of semiliquid material or to divide this material into particles of uniform size. Tests involving air-driven equipment were therefore discontinued and endeavors were centered on studies of power-operated types.

Generally, in the application of insecticides containing adhesives it is the practice to mix the ingredients before distribution. The objection to this procedure is the difficulty of maintaining uniform distribution without eventual clogging of the apparatus and inevitable decrease of efficiency. Furthermore, no adhesives are available that can be added in dust form prior to distribution which will insure satisfactory adherence of the insecticide under all conditions.

As a result of the studies in the test room at Greenfield a method of handling insecticices was evolved which offered promise. This method is one of dispersing dust materials in measured quantities and simultaneously but separately releasing liquids, such as adhesives, emulsions, and water, in such a manner that the dust particles are coated with liquid. This coating process occurs outside the apparatus and in such a way that liquid particles unite with a large proportion of the dust particles, thus avoiding clogging or fouling of the dispersing apparatus. The elimination of water as a carrier and the use of air substantially increase the amount of insecticide that can be transported in mobile equipment—an obvious advantage, particularly where aircraft is involved.

PRELIMINARY TESTS.—The first of a series of field tests utilizing this method was conducted on August 28, 1937, in Wendell State Forest in Massachusetts. An apparatus for simultaneously discharging lead arsenate dust and atomized fish oil was mounted on a light automobile truck, from which all unnecessary parts had been removed. The materials were released in a cloud to the side and beyond the rear of the machine. The truck was driven between 40 and 50 miles per hour along roads that had been conditioned for the purpose.

Although the apparatus was experimental in design and not mechanically perfect, the results demonstrated that the principle of air-blending dust and liquid so as to produce a combination which would adhere to foliage, was sound. Consequently, in April 1938 an autogiro was procured for the purpose of studying the possible use of the method in conjunction with aircraft. An apparatus based in general design on that tested in the woodland-roadside treatments was installed in this autogiro.

The equipment consisted of containers built into the fuselage of the aircraft for carrying both dust and liquid materials. The dust hopper, with a maximum capacity of 450 pounds of lead arsenate dust, and two tanks for the liquid, each of 15 gallons capacity, were located in the forward cockpit of the autogiro in such a manner that the center of gravity of the aircraft was altered only slightly, regardless of load variations. Beneath the fuselage a Venturi tube was suspended by suitable struts, and a vertical duct, provided with a slide valve, connected an opening in the bottom of the hopper to an opening in the top of the Venturi about midway of its approximately 5-foot length. Mounted coaxially in the tube was a hollow rotatable shaft, to the rear end of which was attached a hollow cone. This cone was closed at the base except for an opening around its greatest circumference. A small air-cooled gasoline engine was mounted in front of and above the Venturi tube, immediately beneath the autogiro engine cowling. A V-belt drive from the gasoline engine was used to rotate the shaft and attached cone at high speed. A similar transmission was used to drive a short section of continuous-flight conveyer-screw, so arranged in the bottom of the hopper that the dust could be measured

and positively discharged through the opening at the bottom of the hopper and consequently into the Venturi.

Fish oil was introduced from the tanks, through a gear pump and suitable tubing, into the forward end of the hollow shaft, and hence into the interior of the cone. The gasoline engine was directly connected to the gear pump, permitting a positive measuring of the liquid from the tanks through the shaft and into the rotating cone. The oil was delivered under a pressure of approximately 15 pounds per square inch.

The conveyer screw metered the lead arsenate into the Venturi tube, where the air stream travelling through the latter entrained the dust particles and conveyed them in a hollow cylindrical cloud around the cone and eventually into the combined slip stream of the autogiro propeller and rotor down-blast.

Owing to the high peripheral speed of the base of the cone, the liquid was atomized and thrown into the passing cloud of dust particles. As long as the rotation of the cone was maintained at a uniform speed the size of the atomized particles would remain reasonably constant. The amount of dust dispersed was uniform at all times as long as the feed screw in the hopper rotated at a constant speed. Uniformity in speed of these parts of the apparatus was obtained by operating the gasoline engine at a set speed.

FLIGHT TESTS.—Numerous tests made under flight conditions in September and October 1938 indicated that the method of distribution under development was feasible and that the equipment constructed was capable of applying dust materials from the air in such a manner that they adhered to foliage. The need for improvement in certain mechanical features of the distributing apparatus was apparent, however, and this was not unexpected in view of the highly experimental nature of the equipment. The design of this equipment involved engineering problems on which there was very little, if any, background, and construction suitable and safe for use in aircraft required precautions that would not have been necessary where ground equipment was concerned.

FIG. 1.—Autogiro used in the tests. The mounting of the Venturi tube may be noted.

GYPSY MOTH CONTROL TESTS.—Upon completion of modifications considered necessary or desirable, the equipment and process were subjected to field tests in June 1939 in treating an area infested with the gypsy moth. Two 50-acre plots were selected near Greenfield in a hilly, wooded section where an infestation had been known to exist for several years. Lead arsenate was applied to these plots at the rates of 40 and 20 pounds per acre by

means of the autogiro and the apparatus described. Performance of the equipment in carrying out these treatments indicated that further mechanical improvement was necessary to obtain a union of all the dust and oil particles released.

Following an inspection of these plots in November, S. F. Potts, of the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, reported that no egg clusters were found in the plot receiving 40 pounds of lead arsenate per acre. In the adjoining check plot 264 egg clusters per acre were found. In the plot receiving 20 pounds of lead arsenate only 4 egg clusters were found, as compared with 52 per acre in the adjoining check plot. Owing to variable weather conditions during the treatment of the two plots, and because of the small areas involved, these results should not be regarded as definite evidence of the comparative effectiveness of the two dosages in gypsy moth control.

In treatment of woodlands with a high-pressure ground sprayer the amount of lead arsenate applied per acre ranges from 30 to 40 pounds, depending on the type of forest growth and the degree of infestation.

Mention has been made of weakness in equipment design, permitting the escape of dust from the release apparatus with insufficient or no combination with the adhesive. To date no method has been evolved of accurately determining what percentage of the total amount of dust released this portion represents. Development of such a method would aid materially in indicating the mechanical change necessary.

Although the process and equipment were developed for use in applying lead arsenate to woodlands from the air in gypsy moth control, the result indicates that the method can undoubtedly be utilized for treating field and orchard crops from the ground. In this connection changes in the design of the dispersing apparatus will of course be necessary.—8-12-40.

Some Factors Influencing Feeding Activity of Simuliids in the Field

G. W. UNDERHILL, *Virginia Agricultural Experiment Station, Blacksburg*

Observations on the feeding of simuliid flies on turkeys show that there is considerable fluctuation in the activity of the flies. There may be times ranging from a few minutes to a whole day when no flies appear, or they may appear in large numbers and swarm around and crawl over turkeys without any, or at most very reluctant feeding; whereas at other times they appear and feed readily, often appearing with a vim and feeding promptly.

An attempt has been made to find a relationship between the reaction of the flies in the field and certain of the meteorological factors. The four factors, temperature, relative humidity, air currents, and atmospheric pressure are considered dominant in their effect on the feeding of the flies. This paper deals only with these factors. Other meteorological factors, as thermal convection, electrical state of the atmosphere, and variations in the amount of ozone in the air during and after thunderstorms were not considered. The movement of objects, as a man, an auto, a turkey, or an insect net seemed to attract the flies and probably influenced the results obtained. The age of the fly and degree of hunger, no doubt, influence the feeding but were not considered in this study.

These data were secured while collecting blackflies in the act of feeding on a turkey infected with a protozoan disease.

METHODS.—On many occasions and under different weather conditions, a turkey was taken to localities where flies were known to be present. The relative number of flies observed and the number feeding on the turkey were recorded. Notes were made on the weather conditions as follows: on temperature, from 1936 to 1939, inclusive; on relative humidity in 1938 and 1939; and on atmospheric pressure in 1939. The air movement was estimated from the movement of smoke, leaves and limbs of trees, and dust in the roadways.

TEMPERATURE.—The flies were observed swarming around at temperatures

of 65 degrees to 95 degrees F. Maximum feeding took place at 75 degrees to 85 degrees F., (Figs. 1 and 2); 83 per cent fed within this 10 degree range with the peak around 80 degrees F. Little feeding took place at temperatures below 70 degrees F.,

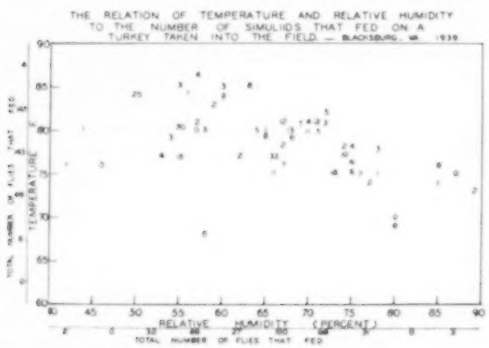

THE RELATION OF TEMPERATURE AND RELATIVE HUMIDITY TO THE NUMBER OF SIMULIIDS THAT FED ON A TURKEY TAKEN INTO THE FIELD — BLACKSBURG, VA. 1939
TEMPERATURE
RELATIVE HUMIDITY (PERCENT)
TOTAL NUMBER OF FLIES THAT FED

FIG. 1.—The relation of temperature and relative humidity to the number of simuliids that fed on a turkey taken into the field. A total of 349 engorged flies included in the data. Blacksburg, Virginia. 1939.

and feeding activity was retarded at a temperature of 90 degrees F. or more. Although there was a wide range of temperature at which the flies were on the wing, it is apparent that temperature is an important factor in the feeding activity of the insect.

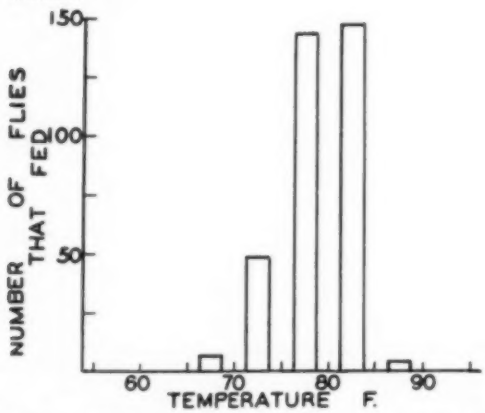


FIG. 2.—The relation of temperature to the number of blackflies that fed; 83 per cent fed between 75 and 85 degrees F. with the optimum near 80 degrees F.

RELATIVE HUMIDITY.—The data indicate that the blackfly has a greater range of tolerance to relative humidity than to temperature, especially as regards feeding. They fed at humidities as low as 42 per cent and as high as 89 per cent (Figs. 1 and 3); 80 per cent fed between 55 and 75 per cent relative humidity with the peak between 65 and 75. Few flies fed at humidities below 50 per cent and above 80 per cent. It will be noted, however, that the observations at these humidities were made under unfavorable temperature conditions. That there is a relationship between humidity and temperature is shown in figure 5. A rise in temperature is usually accompanied by a decrease in humidity, and a fall in temperature by an increase in humidity; and any correlation between the feeding activity and relative humidity might be interpreted as a temperature relationship rather than a humidity relationship. A study of figure 1 supports this conclusion. It will be seen in the figure that all the large numbers observed fall

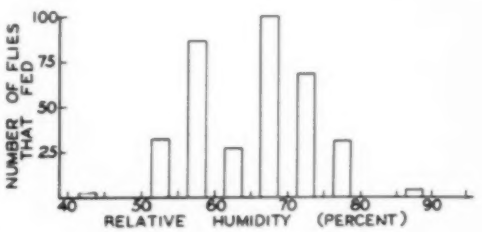


FIG. 3.—The relation of relative humidity to the number of blackflies that fed; 80 per cent fed between 55 and 75 per cent relative humidity with the optimum near 70 per cent.

within a comparatively narrow range of temperature but that they are scattered over a wide range of humidity with little relationship indicated.

AIR CURRENTS.—Flies appeared and fed more readily when the air was calm or when there was only enough breeze to move the leaves and small terminal limbs on trees. They rarely or never appeared when the wind was strong enough to sway large limbs and treetops or to blow up dust in the road or field. They fed during calm intervals, however, on windy days when other factors were favorable. The failure of flies to feed on many occasions, in the experience of the writer, was not due to the absence of flies but to the high winds at the time of the observations.

There seemed to be a relationship between the direction of the wind and the feeding activity of the blackflies. They seemed to feed less during an east or northeast wind than during a south or west wind of the same velocity. The atmospheric pressure was rising or was high and

the temperature generally low at the time of the observations when the wind was from the east or northeast, and these factors were likely responsible for the decrease in the activity of the flies rather than the direction of the wind.

ATMOSPHERIC PRESSURE.—The flies were most active in feeding when the barometric pressure was 27.85 to 28.05 inches (elevation, 2,000 feet) (Fig. 4). A drop in atmospheric pressure was associated with an increase in feeding activity other conditions being favorable, and apparently the more rapid the change the greater the effect on the insect (Fig. 5). On days when such conditions prevailed, flies swarmed around in large numbers whether a turkey was present or not; and on days when the atmospheric pressure was high, few or no flies appeared.

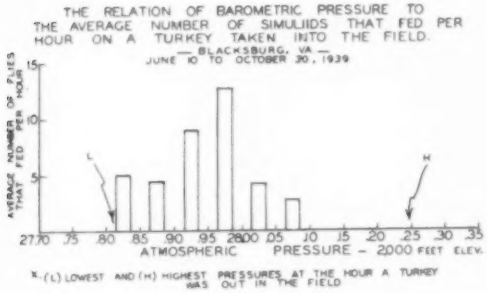

THE RELATION OF BAROMETRIC PRESSURE TO THE AVERAGE NUMBER OF SIMULIIDS THAT FED PER HOUR ON A TURKEY TAKEN INTO THE FIELD.
— BLACKSBURG, VA. —
JUNE 10 TO OCTOBER 20, 1939
AVERAGE NUMBER OF FLIES THAT FED PER HOUR
15
10
5
L
H
27.70 .75 .80 .85 .90 .95 28.00 .05 .10 .15 .20 .25 .30 .35
ATMOSPHERIC PRESSURE – 2000 FEET ELEV.
X (L) LOWEST AND (H) HIGHEST PRESSURES AT THE HOUR A TURKEY WAS OUT IN THE FIELD

FIG. 4.—The relation of barometric pressure to the average number of simuliids that fed per hour on a turkey taken into the field. All feeding, under the conditions of these records, took place at a relatively low barometer reading. A drop of around 0.25 inch, or more, pressure seemed to influence the feeding activity favorably.

SUMMARY.—A study was made on the feeding activity of blackflies on turkeys as influenced by the meteorological factors, temperature, humidity, atmospheric pressure, and air currents. There was a definite relationship between the feeding of

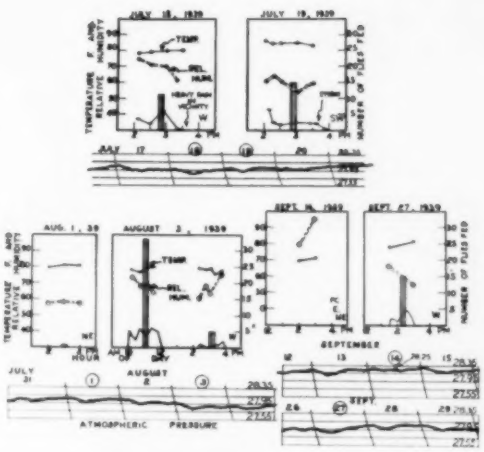


FIG. 5.—The temperature, relative humidity and barometric pressure are shown in relation to the number of blackflies that fed on a turkey taken into the field on six representative days. The flies fed well on July 18, 19, August 2 and September 27 when the barometer was low, while none were seen on September 14, and only one fed August 1 when the barometer was high. The shaded perpendicular column represents the total number of flies that fed during the period indicated. Other conditions being equal the flies fed best on a falling or low barometer.

the insects and temperature, maximum feeding taking place at temperatures of 75 to 85 degrees F. The flies were observed feeding at humidities as low as 42 per cent and as high as 89 per cent. Apparently humidity was not an important factor in the feeding activity of the insect.

The flies were mostly active in feeding at a low atmospheric pressure or following a rapid fall in the barometer. Maximum feeding took place at barometric pressures of 27.85 and 28.05 inches (at 2,000 feet elevation).

Strong wind prevented feeding of the flies. They fed most actively when there was a calm or, at most, only a light breeze. —7-30-40.

THE W. S. BLATCHLEY CLUB TAKES OVER THE SALE OF THE BLATCHLEY INSECT AND NATURE BOOKS

The W. S. Blatchley Club of Noblesville, Indiana, has taken over all the available volumes of the works of the late W. S. Blatchley. Entomologists may be interested to know that some of the volumes on insects are still available. Communications should be addressed to the club in care of Earl Brooks, Librarian.

OKRA QUARANTINE

THE finding of several cases of infestation of commercial okra by larvae of the pink bollworm, in all instances in early stages which would be extremely difficult to detect by the usual inspection procedure, has led the Bureau of Entomology and Plant Quarantine to issue a notification under the Fruit and Vegetable Quarantine (No. 56), excluding okra from Mexico, effective August 15, 1940.

The Ratio of Lead to Arsenic in Spray Residues from Lead Arsenate. II[1]

G. W. Pearce and A. W. Avens, *N. Y. State Agricultural Experiment Station, Geneva*

In a previous paper the authors (Pearce & Avens 1938) have presented data to show that under conditions prevailing in New York State the ratio of lead to arsenious oxide in residues at harvest from lead arsenate sprays tends to be higher than the ratio in dilead arsenate. Recently Fahey & Rusk (1939) have concluded from experiments carried out in another state that the ratio in samples taken immediately after spraying showed no significant difference from those taken after periods of weathering. Since studies of the weathering of spray deposits are of interest from both a theoretical and a practical viewpoint we have considered it important either to confirm or discredit our previous study (Pearce & Avens 1938).

Table 1.—Spraying mixtures applied to Rome Beauty apples on August 7, 1939 and amounts of various constituents per 100 gallons.

Plats	Lead Arsenate	Hydrated Lime	Micronized Sulfur	
1	3 lbs.			
2	3 lbs.	3 lbs.		
3	3 lbs.	6 lbs.		
4	3 lbs.	6 lbs.		Copper sulfate ½ lb.
5	3 lbs.	6 lbs.		Copper sulfate 1½ lbs.
6	3 lbs.	3 lbs.		*Coposil* 1½ lbs.
7	3 lbs.	3 lbs.	5 lbs.	
8	3 lbs.	3 lbs.	8 lbs.	
9	3 lbs.	3 lbs.	5 lbs.	Aluminum sulfate 1 lb.
10	3 lbs.	3 lbs.	5 lbs.	*Spraysoy A* 1½ lbs., Orthol-K 1 pint
11	3 lbs.	3 lbs.	5 lbs.	*Orthex* 1 pint
12	3 lbs.	3 lbs.	5 lbs.	*S. E. C.* 1 pint
13	3 lbs.	3 lbs.	5 lbs.	*S. E. C.* ½ pint
14	3 lbs.	3 lbs.	5 lbs.	*Filmex* ½ pint
15	3 lbs.	3 lbs.	5 lbs.	*S S 3* 1½ oz.
16	3 lbs.	3 lbs.	5 lbs.	*Pyrolene* 1 pint
17			5 lbs.	

* *Coposil*—copper fungicide; *Spraysoy A*—soybean flour spreader; *Orthex*—spreader adhesive; *S. E. C.*—miscible vegetable oil; *Filmex*—spreader; *S S 3*—spreader sticker; *Pyrolene*—spreader.

An opportunity to reinvestigate the problem occurred during the 1939 season. The results offer such clear cut support for our previous findings and in addition furnish further information concerning the effect of various supplementary spray materials upon the ratio of lead to arsenious oxide in spray residues, that we feel justified in publishing them.

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 387, June 26, 1940.

Experimental Method.—A Rome Beauty orchard located near Poughkeepsie, N. Y. was divided into plats and treated with the various spray combinations listed in table 1. Three series of samples of fruit were taken for residue analyses as shown in table 2. In the first two series ten fruits averaging 550 and 750 grams respectively were used for the analyses, while in the third series each sample consisted of eight fruits averaging slightly more than 1000 grams per sample.

Arsenious oxide was determined by a modification of the bromate method (A. O. A. C. 1935), whereas lead was determined photometrically using a slight modification of the method proposed by Samuel & Shockey (1934).

Discussion.—The analytical results in table 2 are given in terms of milligrams of lead and arsenious oxide found in each sample rather than in terms of grains per pound of fruit. This is done in order to facilitate statistical analysis of the data as well as to show the comparatively large amounts of residues handled. Previous tests of the analytical methods employed when applied to known amounts of lead and arsenic within the ranges covered by the data enabled us to calculate the standard error for each determination. From this we were able to calculate the standard error (E_q) of each ratio according to the formula shown in table 2. The statistical analysis shows that the changes in the ratios observed are quite significant.

The small amount of residue on the check sample came from sprays applied by the grower previous to the applications made on August 7. These were a calyx spray consisting of 3 pounds of lead arsenate per hundred gallons of water and two early covers each consisting of 1.5 pounds of lead arsenate and 1.5 pounds of calcium arsenate per hundred gallons of water. The influence of these earlier sprays on the ratios obtained is negligible for several reasons. First, the ratio of Pb to As_2O_3 in the blank (Plat 17) is essentially the same as in di-lead arsenate which indicates that most of the calcium arsenate has been

weathered away. Secondly, simple calculations show that only a part of the changes in the ratios observed can be accounted for on the assumption that the early sprays have an influence in this instance. And finally, Plat 1 shows no increase in the ratio and hence any effect from the earlier sprays must be considered negligible. The increase shown in the ratio of the check (Plat 17) in Series 2 should be expected since the residues are fully exposed to weathering processes and any ering process. Since the other spray plats include lime it must be assumed that its influence on weathering is present. Of considerable interest is the fact that those sprays containing copper (Plats 4, 5, 6) and that containing aluminum (Plat 9) do not show as great a change in the ratio as the other plats containing lime. This observation certainly fits in with the general experience that copper and aluminum in various forms can act as arsenical injury correctives and hence would be ex-

Table 2.—Residue loads and ratios of lead to arsenious oxide in spray residues on Rome Beauty apples before and after weathering, 1939.

	Series 1 24 hours after spraying (Aug. 8)‡				Series 2 21 days after spraying (Aug. 28)‡				Series 3 70 days after spraying (Oct. 17—harvest)‡			
Plat	Residue Load mgs. per 10 fruit Pb	As_2O_3	Ratio Pb/As_2O_3	*Eq	Residue Load mgs. per 10 fruit Pb	As_2O_3	Ratio Pb/As_2O_3	*Eq	Residue Load mgs. per 8 fruits Pb	As_2O_3	Ratio Pb/As_2O_3	*Eq
1	17.00	7.89	2.15	±.04	14.00	6.75	2.07	±.05	9.00	4.43	2.03	±.01
2	17.00	8.25	2.06	.04	12.04	5.01	2.40	.06	8.16	2.88	2.83	.02
3	10.96	5.32	2.06	.01	5.72	2.31	2.48	.03	4.92	1.77	2.78	.04
4	13.00	6.72	1.93	.05	9.28	4.14	2.24	.02	4.68	2.07	2.26	.03
5	14.60	7.07	2.06	.04	10.80	5.04	2.14	.01	No sample taken			
6	11.76	5.61	2.10	.01	10.40	4.68	2.22	.01	No sample taken			
7	13.32	6.22	2.14	.05	9.48	3.75	2.53	.02	4.24	1.44	2.94	.05
8	8.88	4.13	2.15	.02	6.40	2.55	2.51	.03	5.12	1.68	3.05	.04
9	12.60	6.58	1.91	.05	9.60	4.32	2.22	.02	5.80	2.46	2.36	.03
10	8.40	4.16	2.02	.02	9.20	3.72	2.47	.02	7.28	2.85	2.55	.02
11	12.60	6.38	1.98	.05	11.48	4.65	2.47	.01	8.24	2.97	2.77	.02
12	8.24	3.87	2.13	.02	9.76	3.96	2.47	.02	6.40	2.40	2.67	.03
13	12.40	6.33	1.96	.05	8.80	3.45	2.55	.02	7.12	2.49	2.86	.03
14	9.44	4.59	2.06	.01	10.28	4.11	2.50	.02	†5.60	1.95	2.87	.03
15	13.00	6.45	2.02	.05	10.80	4.32	2.50	.02	8.00	3.00	2.67	.02
16	9.00	4.28	2.10	.02	11.32	4.65	2.43	.01	5.92	2.16	2.74	.03
17	0.56	0.28	2.00	.09	0.60	0.21	2.86	.15	No sample taken			

$$*\text{Eq} = \frac{\sqrt{\frac{(Ba)^2}{(A)} + b^2}}{A} = \text{standard error of the ratio } \frac{B}{A}.$$

$\frac{B}{A}$ = Ratio $\frac{Pb}{As_2O_3}$; b = standard error of B = ±.015 from 0 to 3.00 mgs., ±.06 from 3.01 to 12.00 mgs.; ±.30 for more than 12.00 mgs. a = standard error of A = ±.01 for all determinations in this work.

† This sample was also analyzed for lead by the Dithizone method and found to contain 5.70 mg. of lead.

‡ Rainfall record: Aug. 8–Aug. 28 = 1.30 inches; Aug. 29–Oct. 17 = 3.49 inches.

changes are not masked by any other sprays.

Several important observations can be noted from the data in table 2. In Plat 1 no significant change in the ratio occurred even after 70 days weathering. This is accounted for by the fact that lead arsenate alone was applied. We may conclude that the hydrolysis of di-lead arsenate to basic lead arsenate is not an important factor in the weathering of lead arsenate residues. On the other hand Plat 2 and Plat 3 were sprayed with lead arsenate and lime and there is a large change in the ratio. This indicates that the reaction between lead arsenate (Streeter & Pearce, 1931) and calcium carbonate (formed from the lime) plays a very important role in the weathpected to suppress the loss of soluble arsenic from residues and influence ratios accordingly. The ratio changes observed in Plats 7, 8 and 17 suggest that sulfur probably tends to increase the ratio. The effect of the other spray supplements (Plats 10–16 incl.) is not pronounced although a slight depressing effect is noticeable in some instances.

We have called attention in the foregoing discussion to a number of significant observations. Now we would like to show that actually the present data as well as that already published (Pearce & Avens 1938) are not entirely in disagreement with Fahey & Rusk (1939) and completely confirm our previous findings. Let us point out first that the data presented

answer the implied conclusion of Fahey & Rusk that the changes in the ratio observed in our previous work were probably due to inadequate samples or to unreliable methods of analysis. Aside from this conclusion these authors failed to recognize a number of factors operating under their experimental conditions which would tend to mask or suppress any changes in the ratio of Pb to As_2O_3. It should be noted that they used either bordeaux mixture or oil or both in all of their spray treatments. Bordeaux is shown in the present paper to have a marked suppressing effect on changes tending to occur. In our previous paper oil was also shown to have the property of suppressing changes in the ratio. Thus at least two factors are inherent in their experiments which probably would have prevented any large changes in the ratios. A third factor of primary importance involves consideration of the question as to whether decomposition of a spray continues after another has been applied on top of it. From a mechanical viewpoint one would expect the top spray or sprays to hinder decomposition of those underneath. Finally, one cannot ignore the fact that the last sprays applied during a season make up the bulk of the residues present on the fruit, because of the growth factor. These latter sprays are not subject to such long periods of weathering and hence do not usually show extensive decomposition. Thus, they tend to mask any changes which may have occurred in the earlier sprays because of their predominance. Fahey & Rusk applied 4 to 10 covers of lead arsenate and for the most part there were only relatively short weathering periods. Where longer periods were involved the situation was complicated by application of oil sprays. Apparently they assumed that the first sprays applied could be considered as being subject to weathering factors throughout the season regardless of the effect of subsequent sprays. In general we would expect to obtain similar results from spray programs such as those considered by Fahey & Rusk (1939). It must be kept in mind that there are some fruit growing areas in which the number of cover sprays applied during a season is not more than three. Thus the data furnished in the present paper would apply to such areas. In those regions where large numbers of cover sprays are applied, the findings of Fahey & Rusk might well be experienced.

CONCLUSIONS—1. No changes in the ratio of lead to arsenious oxide in spray residues from lead arsenate alone were observed.

2. The addition of lime to lead arsenate sprays produces conditions which tend to result in an increase in the ratio of Pb to As_2O_3 after more or less prolonged periods of weathering.

3. The presence of materials such as bordeaux mixture, *coposil* and aluminum sulfate which can act as arsenical injury correctives tends to suppress any changes in the lead arsenate spray deposits brought about by lime or other materials having an opposite effect.

4. Oil sprays applied with or following lead arsenate sprays also tend to suppress any changes in the composition of the residues.

5. As the number of lead arsenate cover sprays applied is increased, the ratio of Pb to As_2O_3 in the residues at harvest tends to approach that in di-lead arsenate. —8-5-40.

ACKNOWLEDGEMENT.—The authors take this opportunity to express their appreciation to Dr. O. H. Hammer of this Station for applying the sprays and taking the samples for analysis reported in this paper.

LITERATURE CITED

Association of Official Agricultural Chemists. 1935. Official and tentative methods of analysis, 4th ed., pp. 373–5.

Fahey, Jack E., and Harold W. Rusk. 1939. Possible changes in ratio of lead to arsenious oxide in lead arsenate residues on apples. JOUR. ECON. ENT. **32**(2): 319–22.

Pearce, G. W., and A. W. Avens. 1938. The ratio of lead to arsenic in spray residues from lead arsenate. JOUR. ECON. ENT. **31**(5): 594–7.

Samuel, B. L., and H. H. Shockey. 1934. A rapid and accurate photometric method for determination of lead in small quantities. Jour. Assoc. Offic. Ag. Chem. **17**: 141–6.

Streeter, L. R., and G. W. Pearce. 1931. Reactions involved in the use of hydrates in lead arsenate sprays. Jour. Ind. Eng. Chem. **23**: 1140.

Fumigation of Sweetpotatoes with Methyl Bromide for Control of the Sweetpotato Weevil

STEPHEN S. EASTER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

The sweetpotato weevil (*Cylas formicarius* (F.)) is at present found in Texas, Louisiana, Mississippi, Alabama, Florida, and Georgia. It attacks the vines and roots of the sweetpotato, making the roots unfit for human consumption. The entire egg, larval, and pupal stages and part of the adult stage are spent within the vines or roots. The larvae leaves frass-filled tunnels as they feed. From early in January until late in March, in areas where the weevil is found, the sweetpotatoes are bedded for propagating purposes under 2 to 4 inches of soil, where they sprout. The sprouts, or draws, are pulled up when 6 to 10 inches long and set out in the field. The object of fumigating the seed is to destroy all stages of imbedded weevils in order to prevent the spread of the insect.

The problem of fumigating sweetpotatoes to kill the imbedded sweetpotato weevil has been studied by several workers, who have used various materials, including carbon disulfide, paradichlorobenzene, and methyl bromide.

Among those using carbon disulfide were M. M. High and F. A. Johnston, of the Bureau of Entomology and Plant Quarantine, who in 1916 obtained a complete kill of the sweetpotato weevil, but with such severe injury to the sweetpotatoes that the fumigant was not recommended (unpublished data). A year later Newell (1917) stated that all stages of the weevil were destroyed by fumigating with this chemical in tight containers. Chittenden (1919) recommended the use of carbon disulfide, but, recognizing that many factors affecting success with this fumigant were yet to be worked out, advised sweetpotato growers to use it with extreme caution. Reinhard (1923) recommended the use of carbon disulfide, giving a definite dosage, but he also recognized the possibility of injury to the sweetpotatoes. Fukuda (1933) stated that the fumigant was not widely used in Japan, and pointed out that treated roots decayed, lessening their ability to sprout, and that fumigation did not entirely eliminate infestations.

The use of paradichlorobenzene as a fumigant has been attempted by several workers. High and Johnston began using it experimentally in 1916 and continued their work intermittently until 1925. As a result of their experiments a fumigation of 21 days duration was recommended with a dosage of 1 ounce per crate[2] of sweetpotatoes. This treatment was confirmed by Cockerham (1935), and his recommendations have been accepted and used by many growers in the Gulf States. The disadvantages of this treatment are that the fumigation period is long and subsequent sprouting of the treated sweetpotatoes in the seed bed is retarded.

Dozier (1939) tested a number of chemicals as fumigants for controlling the sweetpotato weevil. Methyl bromide was among these, and in a few preliminary experiments it exhibited an extremely high toxic effect on larvae, pupae, and adults imbedded in roots. No consideration was given to its effect on the sweetpotato, his work being done with old roots in May, June, and July, when they were well cured and hence less susceptible to injury. Methyl bromide, now coming into general use as a fumigant for a number of commodities, has been shown to have a low toxic effect on plants and vegetable materials. Mackie & Carter (1937) have reported marked success in preliminary tests on Irish potato tubers, ferns, pansies, begonias, *Kentia* palms, and certain cut flowers, and Hawkins (1938) has reported on its use for quarantine purposes.

The immediate objective of the research reported in this paper was to determine if methyl bromide could be used as a fumigant to destroy infestations of the sweetpotato weevil in sweetpotatoes, when applied at concentrations that would require relatively short exposures to the gas and without causing appreciable harm to the

[1] The writer was assisted by Baker J. Guilbeau, of the Bureau of Entomology and Plant Quarantine. This work was done in cooperation with the Louisiana Department of Agriculture and Immigration, which furnished working quarters, infested materials, some equipment, and unpublished notes of workers formerly engaged in work on the control of the sweetpotato weevil.

[2] There are approximately 50 pounds or 1 bushel of sweetpotatoes in a crate.

sweetpotatoes. The work was done at Sunset, Louisiana.

EQUIPMENT AND SWEETPOTATOES USED.—Fumigations were carried out both at reduced and at atmospheric pressures. For the studies at reduced pressure a vacuum chamber having a volume of 50 cubic feet and a pump capable of reducing the atmospheric pressure initially to the equivalent of 4 inches of mercury (a 26-inch vacuum at sea level) was used. The studies at atmospheric pressure were conducted in three 100-cubic-foot wooden chambers, each of which was equipped with a fan and one with a thermograph. Another chamber having a capacity of 25 cubic feet was constructed of 28-gage galvanized iron and insulated with 1½ inches of bagasse board. A thermostat mounted in this chamber, controlling a strip heater and fan, made it possible to hold the temperature within about 4 Fahrenheit degrees.

Table 1.—Mortality of third-instar larvae and pupae of the sweetpotato weevil at various intervals after dissection from the roots 48 hours after fumigation with methyl bromide.

DAYS AFTER DISSECTING FROM ROOTS	PERCENTAGE MORTALITY			
	Fumigated Larvae	Unfumigated Larvae	Fumigated Pupae	Unfumigated Pupae
3	17.4	0.5	13.9	0.7
5	40.7	1.1	24.0	2.0
7	52.2	3.8	30.0	3.1
9	68.3	7.0	36.0	3.9
11	77.8	13.6	41.2	4.8
13	83.3	20.7	46.5	7.2
15	88.7	28.3	49.5	9.3
Specimens Observed	1,905	2,092	474	1,518

The sweetpotatoes used in the experiments were nearly all of the Puerto Rico variety, as this is the leading variety in the area involved, and the data here given should be considered as applying only to that variety.

EXPERIMENTAL PROCEDURE.—During the preliminary work experiments were run over a wide range of dosages, exposures, temperatures, and loads at reduced as well as atmospheric pressure. Certain dosages were studied with the time varied, and all factors were held as nearly constant as the equipment allowed. Replications were run at the high mortalities as extensively as time and material permitted. This work was done mainly from September through December in 1937 and 1938 while naturally infested sweetpotatoes were available in abundance.

In preliminary experiments it was found that a complete kill of all stages of the weevil imbedded in sweetpotatoes could be obtained with low dosages of methyl bromide at either reduced or atmospheric pressure. In these experiments the insects were dissected out of the roots and placed in petri dishes 48 hours after fumigation was completed, and the numbers dead and living were determined. When the examination was made at a longer interval fter fumigation, the mortality was found to be higher. There was a much higher death rate among the weevils from the fumigated potatoes than among insects from potatoes handled in the same way except not fumigated. Infested sweetpotatoes were fumigated at dosages that would give less than complete mortality. The third-instar larvae and the pupae were removed from the roots after 48 hours, and held under observation until all had either died, pupated, or emerged. The insects were not recorded as dead until there was a definite discoloration of the tissue. Similar larvae and pupae were removed from unfumigated infested sweetpotatoes and held under the same conditions. The results of observations at 2-day intervals (table 1) indicate that the action of methyl bromide is delayed and that a reliable determination of its effect could not be obtained 48 hours after the fumigation. In subsequent experiments, therefore, the weevils were dissected out 48 hours after the fumigation was completed and observed for 8 days. Later all sweetpotatoes were allowed to stand for at least 10 days after the fumigation before being dissected. All moving weevils were considered to be alive.

In the experiments at reduced pressure a constant dosage of 40 ounces per 1,000 cubic feet was used for exposures varying in 15-minute periods. The pressure in the chamber was reduced to the equivalent of 4 inches of mercury, the unheated liquid fumigant was then introduced, and the pressure was brought up to 5 inches, where it was held throughout the fumigation period. At the end of the exposure the air pressure was brought to normal, and

the treated sweetpotatoes were removed without air-washing. The load was in bushel crates and varied from one-half crate to 2 crates.

At atmospheric pressure a wide range was covered in dosage, time, load, and temperature. Dosages of from 5 to 160 ounces per 1,000 cubic feet were used, with exposures of from 1 to 72 hours. The load was varied from one-half crate to 42 crates of sweetpotatoes per 100 cubic feet and the temperature from 45 degrees to 100 degrees F. The liquid fumigant was introtroduced through a glass tube in the top into a pan suspended 6 inches from the ceiling. The fan was set to direct a flow of air at this pan. The fumigant was measured in a graduated cylinder and cooled below the boiling point before being introduced.

The effect of temperature during fumigation was not thoroughly studied, but several comparisons were possible, all of which showed a decided increase in weevil mortality with a rise in temperature. In these studies the infested sweetpotatoes were maintained at the temperature to be used in fumigation at least overnight or until they had reached the desired temperature. It was found desirable to conduct the fumigation at 70 degrees F. or above. This required special heating rooms, as sweetpotatoes are stored at 55 degrees F. and the temperature may range from 45 degrees to 65 degrees F. during the bedding season. The storage house, or kilns as they are called in the vicinity of Sunset, Louisiana, are unheated.

FACTORS AFFECTING FUMIGATION AND BREAKDOWN OF SWEETPOTATOES.—Following fumigation with methyl bromide decay sometimes occurs which is apparently due to some physiological condition of the root. This decay may be followed by secondary storage rot, and the prevalence of this rot may vary with a number of factors, chief of which are dosage, exposure, condition of sweetpotatoes, and temperature after as well as during the fumigation. Cured sweetpotatoes can be most successfully fumigated at dosages to kill all weevils, because bruises have had time to heal completely, and less fumigant or a shorter exposure is required than for freshly dug sweetpotatoes.

The postfumigation temperature was found to have an important influence on the percentage of loss. This is shown strikingly in the results of experiments in table 2. Three lots of sweetpotatoes were treated at the same time with dosages sufficient to give complete mortality of imbedded weevils and held under observation at different temperatures for 21 to 37 days. As the temperature of the storages at Sunset, Louisiana, is 55 degrees F., or below in January and early in February it was found advisable to raise the temperature of the sweetpotatoes before fumigating them and to hold them after treatment at a higher temperature, and this may not entirely prevent decay.

Table 2.—Effect of postfumigation temperature on the breakdown in sweetpotatoes treated with methyl bromide in dosages sufficient to give complete mortality of imbedded weevils.

Lot	Number of Crates	Days Observed after Fumigation	Temperature after Fumigation	Per Cent Loss
1	1	33	50–60° F	35.0
			84	0.6
2	2	37	50° F.*	94.9
			55†	66.1
			84	5.3
3	2	21	60° F.	89.0‡
			84	29.5‡
	1 (check)	21	60	0.0

* Approximate temperature of soil, as these sweetpotatoes were bedded immediately after fumigation.
† Average temperature of the kiln.
‡ A heavier dosage was used on lot 3 than on lots 1 and 2, which accounts for the greater loss.

To determine the normal loss that might be expected from handling of seed sweetpotatoes, an experiment was carried out with 277 bushel crates of seed sweetpotatoes from five farms. The lots were selected to give variation in size and quality. Lots 1 and 5 were small seed, roughly handled with a good deal of bruising; lots 2 and 4 were far better than average seed, being larger and without bruising; and lot 3 was of about average size and quality. These sweetpotatoes were transported to the laboratory, divided at random, and placed in two fumigation chambers. One chamber was fumigated for 4 hours at a dosage of 55 ounces per 1,000 cubic feet while the other was kept as a check under the same conditions. The sweetpotatoes were held at not less than 70 degrees F. for 9 days before they were sorted to

determine the decay. The sweetpotatoes were then returned to the farms and bedded under commercial conditions. The results are given in table 3.

Table 3.—Loss in seed sweetpotatoes due to fumigation handling and to handling alone.

	Sweetpotatoes Fumigated and Handled		Sweetpotatoes Handled Only	
Lot	Number	Per Cent Loss	Number	Per Cent Loss
1	5,858	20.6	7,036	1.4
2	3,822	2.0	3,786	1.5
3	8,005	12.1	8,286	3.6
4	3,882	2.7	3,980	0.6
5	8,084	27.8	4,620	4.5

Size of load, that is, the number of crates of sweetpotatoes per 100 cubic feet of chamber space, will influence the effectiveness of the fumigation. This is shown in several series of experiments, some of which are recorded in table 4. It is noticeable from the table that when the dosage is increased with the increase in load the percentage mortality remains approximately the same, but when the load is increased without the increase in dosage, there is a marked decrease in effectiveness.

Table 4.—Effect of load on the effectiveness of methyl bromide fumigation against the sweetpotato weevil, and on the dosage necessary to produce complete or comparable mortality.

Load, Crates per 100 Cu. Ft.	Dosage Ounces	Exposure, Hours	Number of Tests	Crates Dissected,	Number of Insects	Per Cent Mortality
2	40	5	8	13	4,118	100.00
30	55	5	4	23	1,148	100.00
2	40	4	8	10	1,890	99.36
30	55	4	2	14	1,040	98.84
1	10	24	16	18	2,678	100.00
18	10	24	2	4	1,465	64.03

There is no consistent relationship between the numbers of larvae, pupae, and adults found in sweetpotatoes. Eggs and adults are not so resistant as larvae and pupae. In table 5 it is shown that the pupae are consistently more resistant than the larvae, and that both are much more resistant than the adults. These comparisons do not include first-instar larvae, which have short tunnels mainly in the cortex of the sweetpotato, as the fumigant reaches these and kills them without difficulty while deeply imbedded larvae may survive the same or similar treatment. Eggs naturally imbedded in the cortex were fumigated at a dosage of 15 ounces per 1,000 cubic feet for four hours above 70 degrees F. Six experiments using this treatment were carried out on 56,857 eggs as estimated from suitable checks. Five survivors occurred among eggs 8 days old or less, hatching possibly occurring on the fifth day. Approximately four times this exposure would be required to kill all imbedded stages.

Mortality of the insect is obtained more easily in heavily infested sweetpotatoes than in those lightly infested. The heavily infested roots were used only in preliminary fumigation experiments.

Results of Experiments.—The results of the fumigation experiments are summarized in table 5.

At reduced pressure the mortalities are so high at exposures of 45 and 60 minutes that the latter would be fairly effective for control work in a heavily infested area. An exposure of 90 minutes at the same dosage would be required to be certain the treated sweetpotatoes were weevil-free, and some loss from decay or breakdown could be expected. Since vacuum fumigation chambers are not common in the sweetpotato-growing areas, this treatment is not so well adapted to control work as atmospheric fumigations.

It is of particular interest to note that in both vacuum and atmospheric fumigation a mortality of 90 per cent, or higher, is obtained at a relatively short exposure, but that a much longer exposure is required to obtain 100 per cent mortality. This additional exposure increases the likelihood of loss from breakdown, and raises the question whether in a heavily infested area it is advisable to incur such loss in order to destroy all the weevils in the seed when there are likely to be scattered infestations in the margins of the field on escaped host material. In series 6 to 9 at atmospheric pressure, where the temperatures are below 70 degrees F., with the dosage and period of exposure used, the mortality is considerably lower than in series 1 to 5 at higher temperatures. It is possible that longer exposure at a lower dosage might produce satisfactory results with less injury to the seed sweetpotatoes. During 1939 an exposure of five hours was used for treatment of com-

mercial lots of sweetpotatoes for planting, and the losses from decay and breakdown were not considered prohibitive.

APPLICATION OF EXPERIMENTAL DATA.—During the bedding season of 1939 seed sweetpotatoes were treated with methyl bromide for a number of farmers in the vicinity of Sunset, Louisiana. A constant load of 30 crates per 100 cubic feet was used, as this amount could be conveniently transported in the truck and fumigated as a unit in the 100-cubic-foot chambers. They were taken from farms to the laboratory, held at least 1 day before fumigation, and from 4 to 10 days after fumigation at 70 degrees F. or higher, and returned to the farms to be bedded at the farmers' convenience under customary farm practices. Three treatments were used which previous experiments had indicated would give approximately 95, 99, and 100 per cent mortality of all stages of imbedded weevils. Table 6 gives the results of these tests. The last treatment was satisfactory for local seed fumigations, but is not recommended as a basis for certification for shipment of sweetpotatoes to a clean area, as insufficient experimental evidence is available.

In most cases check seed sweetpotatoes were bedded at the same time as the treated seed. In a number of beds the fumigated seed produced more sprouts, earlier, than the checks. There was no record of the checks being superior. It should be kept in mind that only sound fumigated seed was bedded, all rots being discarded. The bedding took place from 9 days to over a month after fumigation.

Table 5.—Methyl bromide fumigation of sweetpotatoes infested with the sweetpotato weevil at a constant load of one crate per 50 cubic feet, and at varying periods of exposure.

Series	Exposure	Temperature Degrees F.	Number of Experiments	Crates Dissected	Adults		Larvae		Pupae	
					Number Found	Per Cent Mortality	Number Found	Per Cent Mortality	Number Found	Per Cent Mortality
	Minutes	At Reduced Pressure, Dosage 40 Ounces per 1,000 Cubic Feet								
1	90	70–92	22	28	1,789	100.00	3,438	100.00	5,055	100.00
2	75	72–80	2	2	162	100.00	83	100.00	164	100.00
3	60	70–92	12	14	203	100.00	1,408	99.08	1,885	99.52
4	45	72–78	3	3	440	100.00	928	99.46	744	99.87
5	30	73–84	3	3	124	100.00	152	29.65	293	58.36
	Hours	At Atmospheric Pressure, Dosage 40 Ounces per 1,000 Cubic Feet								
1	5	67–87	8	13	1,085	100.00	1,403	100.00	1,630	100.00
2	4	70–89	8	10	261	100.00	1,020	99.31	609	99.18
3	3	73–87	7	9	422	99.53	1,141	94.04	1,033	91.58
4	2	70–84	5	6	298	100.00	412	81.55	500	49.80
5	1	72–73	2	4	78	67.95	286	1.39	424	0.24
6	5	52–67	1	1	6	100.00	58	96.55	16	81.25
7	4	52–65	1	2	4	100.00	31	70.97	10	90.00
8	3	65–69	1	2	14	100.00	141	62.28	13	38.46
9	2	52–58	1	2	16	25.00	207	14.97	252	1.99
10	1	60	2	4	59	23.73	584	5.82	564	0.18
		At Atmospheric Pressure, Dosage 20 Ounces per 1,000 Cubic Feet								
11	10	74–82	1	2	9	100.00	236	100.00	25	100.00
12	8	70–82	3	5	212	100.00	464	98.06	423	95.98
13	7	70–75	2	4	245	100.00	525	95.43	388	91.24
14	6	70–74	2	4	382	100.00	748	96.39	392	91.58
15	5	72–76	2	4	451	100.00	464	92.24	393	71.50
16	4	72–76	2	4	324	100.00	483	67.08	514	36.77
17	3	72–75	2	4	181	100.00	356	19.66	681	3.38

SPROUT GROWTH.—Sweetpotatoes show no loss of viability after fumigation with methyl bromide, except those discarded because of breakdown. There is some evidence that the postfumigation period of heating has a stimulating effect as compared with checks bedded at the same time. However, in one experiment conducted in the spring of 1939 check seed infested without fumigation and two lots of fumigated seed were bedded with seven replications of each treatment, 50 pounds of seed sweetpotatoes being used for each replicate. The sprouts were removed three times. An analysis of variance shows that the checks, the heated seed, and the fumi-

Table 6.—Fumigation of seed sweetpotatoes from farms in vicinity of Sunset, Louisiana, with methyl bromide for control of the sweetpotato weevil at 70 degrees F. or above.

Number of Farms	Number of Crates	Dosage Ounces per 1,000 cu. ft.	Exposure, Hours	Crates Lost by Breakdown	Per Cent Mortality
7	210	45	4	15	91.50
24	767	55	4	108.5	98.84
4	120	55	5	12	100.00

gated seed, with an insect mortality of 91.5 per cent, show no significant difference in the production of sprouts through three pullings. These three treatments gave significantly better results than the fumigation with a mortality of 100 per cent.

SUMMARY.—Methyl bromide is extremely toxic to the sweetpotato weevil (*Cylas formicarius* (F.)), even though the insect is deeply imbedded in sweetpotatoes. A complete kill of all stages of imbedded weevils was obtained at both reduced and atmospheric pressures. It exerts a variable deleterious physiological effect on the sweetpotatoes, which may result in a considerable loss. This loss may be avoided partially by careful handling, partial curing, and postfumigation heating.

Small-scale fumigations run on seed sweetpotatoes from a number of farms gave results satisfactory to the farmers. The loss was not prohibitive, and the production of plants was equal to or better than that in the checks.

The requirement of an airtight fumigation chamber and provision for postfumigation heating may restrict the use of this fumigant to those areas where the sweetpotatoes are raised on a commercial scale. —8-5-40.

LITERATURE CITED

Chittenden, F. H. 1919. The sweetpotato weevil and its control. U. S. Dept. Agr. Farmers' Bul. **1020.**

Cockerham, K. L., and O. T. Deen. 1936. Fumigating sweet potato seed with PDB to control sweetpotato weevil. JOUR. ECON. ENT. **29**(5): 992–1,000.

Dozier, H. L. 1939. Studies of control measures for sweetpotato weevil in Louisiana. JOUR. ECON. ENT. **32**(2): 313–8.

Fukuda, K., 1933. Insect pests of the sweet potato in Formosa. Part I. The sweet potatoweevil. Formosa Gov. Res. Inst. Rpt. **62.** (In Japanese.)

Hawkins, L. A. 1938. Fumigation of plant-quarantined products with methyl bromide. Calif. Dept. Agr. Spec. Publ. **166:** 51–6.

Mackie, D. B., and W. B. Carter. 1937. Methyl bromide as a fumigant. A preliminary report. Calif. Dept. Agr. Bul. **26**(2): 153–62.

Newell, W. 1917. Sweetpotato root weevil. Fla. State Plant Bd. Quart. Bul. **2:** 81–100.

Reinhard, H. J. 1923. The sweetpotato weevil. Tex. Agr. Expt. Sta. Bul. **308.**

Residual Poison Sprays Against the Onion Thrips on Carnations[1]

R. D. EICHMANN, Pullman, Washington

The onion thrips, *Thrips tabaci* Lind., is so injurious to greenhouse carnations in eastern Washington that they may become entirely unsaleable. Damage occurs during the early fall, spring and summer. These seasons are characterized by intense sunlight, high temperatures, and low humidity; climatic conditions which apparently favor the rapid multiplication of thrips. In feeding, the onion thrips punctures the pigment cells on the surface of the petals and ingests the fluid contents. As a result decolorized areas, commonly referred to as "flecks," appear on dark varieties (Fig. 1) and brown petal edges develop on light varieties.

Greenhousemen in this area have been using for years a paris green-brown sugar spray for thrips control on carnations, similar to the formula recommended by Dustan (1931) for gladiolus thrips control. It is used at a much lower concentration however, in order to reduce noticeable residue and injury to the blossoms as it must be used throughout the blooming period. Yet satisfactory control has not been obtained with this combination. It appeared that the small percentage of soluble arsenic in paris green, acting as a residual stomach poison, was the toxicant. Accordingly the possibility of onion thrips control with other soluble insecticides was considered worthy of investigation. The destruction of adult thrips before they deposited eggs or fed upon the petals was the objective.

[1] Published as Scientific Paper No. 465, College of Agriculture and Agricultural Experiment Station, State College of Washington.

REVIEW.—Richardson (1934) carried on an investigation of the value of soluble insecticides for gladiolus thrips control, and concluded that the maintenance of a toxic spray residue on foliage was important in thrips control. The gladiolus thrips prompted the development of many spray combinations, most of which functioned as residual poisons.

Eddy & Sharp (1937) found that Karaya gum markedly increased the effectiveness of nicotine when used against several species of thrips. It seemed possible that nicotine was functioning as a residual poison in this combination although Eddy and Sharp considered Karaya gum solely as an activator of nicotine.

Nelson (1938) reported that tartar emetic 4 lbs. with brown sugar 16 lbs. in 100 gallons of water was as effective against the gladiolus thrips as paris green and brown sugar. Furthermore it was cheaper, since less sugar was required, and it did not injure plant foliage. Boyce & Persing (1939) used tartar emetic effectively for the control of thrips on citrus. While this manuscript was in preparation Anderson & Walker (1940) reported that tartar emetic 2 lbs. plus brown sugar 8 lbs. in 50 gallons of water was effective against onion thrips on onion and bean foliage.

METHODS.—Small plot tests in the greenhouse proved unsatisfactory for testing the effectiveness of residual poisons for onion thrips control on carnations. Conclusive results could not be obtained probably because of the migration of thrips between plots. A laboratory method for testing residual spray combinations which obviated handling the delicate and agile insects was developed for this purpose through modifications of the thrips rearing method of Bailey (1932) combined with the apparatus used by Kearns & Compton (1938) in testing insecticides on red spiders.

FIG. 1.—Buds of red carnations showing severe thrips feeding injury.

Bent glass tubes, 4 mm. inside diameter, were inserted as siphons through No. 8 rubber stoppers into 4 oz. bottles functioning as water reservoirs. Excised carnation leaves inserted in these tubes remained fresh from all outward appearances for two weeks. Five tubes for the leaves, plus one for adding water and a straight tube as an air vent comprised each bottle unit (Fig. 2). The sharpened ends of wooden matches were used as plugs to close the portion of the tube not occupied by the leaf. This prevented the thrips from entering the tubes and drowning. Each bottle so assembled was then sprayed as a unit test.

Materials were applied with a one pint bottle sprayer which gave a fine mist

spray. Care was taken to apply material lightly so that droplets would not coalesce and run off the foliage. Thrips were placed on the sprayed foliage while it was still wet or up to ten days after spraying as the conditions of each test required. In most cases they were caged as soon as the spray dried on the foliage.

FIG. 2.—Apparatus used in caging thrips on sprayed foliage.

Adult thrips for caging on the sprayed foliage were collected by aspiration directly into 20 mm. glass tubing screened with fine mesh cloth. Cork rings were used to hold the cloth in place so as to eliminate hiding places. The glass tubing cages were attached over the sprayed foliage with the aid of a No. 3 rubber stopper placed on the water siphon tubes. Five thrips per cage, or 25 per test, proved to be about all that could be readily observed. The numbers of living and dead thrips were counted at daily intervals either by inspection through the tube or by opening the cage. There were some escapes from this apparatus but they could be readily noted. After completion of a test the tube cages were easily dismantled for thorough cleaning.

From untreated units it was determined that normal mortality increased sharply after 3 days (table 1). Furthermore a spray combination to be effective must destroy the thrips rapidly; so the tests were limited to an interval of 3 days.

LABORATORY RESULTS.—Paris green at the rate of 8 oz. in 100 gallons of water plus 8 lbs. of brown sugar, the standard dilution used by the greenhousemen, was found to produce 50 per cent kill in 3 days (table 2). The effectiveness increased to 80 per cent kill when a concentrated mixture was prepared a week or more before dilution to spraying strength. Still longer standing of the concentrate did not further increase effectiveness. When Paris green was used alone, even at greater concentrations, the kill dropped markedly.

A number of commercial pyrethrum and rotenone spray concentrates in use by greenhousemen were tested for their effectiveness as residual poisons. An acetone extract of derris containing 5 per cent rotenone plus Karaya gum and spreading agents was compared with these. All produced a kill of below 50 per cent at the normal spraying dilutions of about 1 to 500 or .003 to .01 per cent rotenone. At concentrations of 1 to 100, the kill, in some cases, approached 100 per cent 3 days after caging. This effectiveness however diminished rapidly 2 days after spraying.

Nicotine sulfate at the rate of 1 pint in 100 gallons of water plus 1 pint of molasses proved to be an effective combination (table 2), although some of the kill was probably due to fumes in the cages. Mortalities as high as 100 per cent and averaging 80 per cent were obtained on the first or second day after caging, even when the insects were caged 24 hours after spraying, but the combination lost its toxicity 2 days after spraying. Nicotine sulfate alone killed only 50 per cent immediately after spraying and lost its effectiveness rapidly. Molasses alone showed only normal mortality.

Table 1.—Normal mortality of thrips caged on untreated foliage; 25 thrips per test.

NUMBER OF DAYS	1	2	3	4	5	6
Per cent Mortality						
Minimum	0	0	0	20	44	71
Maximum	19	47	81	87	88	100
Average of 24 tests	4	8	20	53		

Nicotine sulfate at the rate of 25½ oz. in 100 gallons of water, plus 13 oz. Karaya gum, with ethyl alcohol to facilitate mixing, and 25½ oz. of pine oil gave good control, 80 to 100 per cent (table 2). Most of the kill was obtained the first day after caging. Even 5 days after spraying it was

as toxic as immediately after drying. After 7 days the kill dropped sharply, although 2 tests showed about 50 per cent kill after 8 and 10 days. Increases in concentration of nicotine sulfate up to 51 oz. per 100 gallons with corresponding increases in the other ingredients gave combinations which retained effectiveness after 7 days. Concentrations of 21 oz. and 17 oz. per 100 gallons gave results comparable to the first combination but weaker dilutions were inferior.

It was considered that nicotine fumes might be responsible for some of the killing. Tests where the cages had air drawn through them by vacuum averaged slightly more than 60 per cent control; however, in this current of air the thrips were observed to be moving about much less than in the other cages. This reduction of movement may account for the apparently lowered toxicity since the thrips failed to come in contact with the spray residue to the same extent. Also the fact that there is some toxicity left in the mixture after as much as 10 days indicates that nicotine fumes contribute only a small part of the killing power.

White arsenic at the rate of 6½ oz. per 100 gallons of water gave no control. At 2 lbs. per 100 gallons the kill was about 75 per cent but foliage was severely burned. Sodium fluoride at the rate of 13 oz. per 100 gallons was ineffective. At 25½ oz. per 100 gallons it was comparable in efficiency to white arsenic and did not produce foliage injury. Mercuric chloride was ineffective at the rate of 6½ oz. per 100 gallons. These materials were all used without brown sugar or other substances which would induce thrips feeding. Indications are that they might prove suitable for thrips control when combined with brown sugar or other spray adjuncts.

Tartar emetic at the rate of 4 lbs. in 100 gallons of water plus 16 lbs. of brown sugar gave about 100 per cent kill. These results were obtained when thrips were caged immediately after spraying or up to 7 days after spraying (table 3). Reductions in concentration to as little as ½ lb. per 100 gallons for tartar emetic and 2 lbs. per 100 gallons for brown sugar gave comparable results, although a little slower in action at the weaker dilutions (table 4). Molasses at the rate of 1 pint per 100 gallons of water proved comparable to brown sugar as a spray adjunct. Corn syrup proved to be another substitute for brown sugar. Recent rests indicate that sucrose

Table 2.—Laboratory tests of paris green with brown sugar, and nicotine sulfate with molasses and Karaya gum. 25 thrips per test.

Amount per 100 Gals. Water				Per Cent Mortality 3 Days After Caging							
Insecticide		Adjunct		No. Tests	Caged when Spray Dried	No. Tests	Caged 24 Hrs. after Spraying	No. Tests	Caged 2 Days after Spraying	No. Tests	Caged 7 Days or more after Spraying
Paris green	½ lb.	Brown Sugar	8 lbs.	3	50%	Freshly mixed	—	—	—	—	—
				3	80%	Concentrated solution mixed more than a week before use.		—	—	—	—
Nicotine Sulfate	1 pt.	Blackstrap Molasses	1 pt.	5	80%	3	86%	1	0%	—	—
Nicotine Sulfate	25½ oz.	Karaya gum Pine oil	13 oz. 25½ oz.	3	90%	3	94%	12	2–5 days 84%	4	22%
Same materials on vacuum draft.				3	57%	1	50%	1	87%	—	—
Nicotine Sulfate	1 qt.	Karaya gum Pine oil	1 lb. 1 qt.	—	—	—	—	—	—	1	87%
Nicotine Sulfate	51 oz.	Karaya gum Pine oil	25½ oz. 51 oz.	—	—	1	100%	—	—	1	100%
Nicotine Sulfate	21 oz.	Karaya gum Pine oil	11 oz. 21 oz.	—	—	—	—	1	100%	—	—
Nicotine Sulfate	17 oz.	Karaya gum Pine oil	8½ oz. 17 oz.	—	—	—	—	1	81%	—	—
Nicotine Sulfate	1 pt.	Karaya gum Pine oil	8 oz. 1 pt.	—	—	1	54%	—	—	—	—
Nicotine Sulfate	13 oz.	Karaya gum Pine oil	6½ oz. 13 oz.	—	—	1	46%	1	69%	—	—

Table 3.—Lasting effectiveness of tartar emetic and the influence of accessory materials in laboratory tests. 25 thrips per test, showing per cent mortality of onion thrips 3 days after caging.

Amount per 100 Gallons of Water									
Tartar emetic	Adjunct	No. Tests	Caged when Spray Dried	No. Tests	Caged 24 Hrs. after Spraying	No. Tests	Caged 4 and 5 Days after Spraying	No. Tests	Caged 7 Days after Spraying
4 lbs.	Brown Sugar 16 lbs.	3	94%	1	100%	1	4 days 96%	1	100%
4 lbs.	Corn syrup 2 gals.					1	5 days 100%		
4 lbs.	Sulphonated Castor Oil 25½ oz.	1	36%						

or white sugar is just as effective as the brown sugar. When used in the laboratory with sulphonated castor oil, tartar emetic proved ineffective. Tests with tartar emetic alone showed that it was relatively ineffective without brown sugar or a similar material. A number of these tests were duplicated on gladiolus thrips, *Taeniothrips simplex* Morison, with approximately the same results (table 4). Gladiolus thrips constitute about 10 per cent of the thrips infesting carnation flowers.

Calcium antimony tartrate at the rate of 4 lbs. in 100 gallons of water plus 16 lbs. of brown sugar was found to give 100 per cent kill 2 days after caging even though the thrips were not placed on the foliage until 6 days after spraying.

GREENHOUSE USE.—On the basis of the results obtained in the laboratory, spray combinations were tried on entire greenhouse ranges over periods of several weeks Some of these tests were premature, occasioned by the fact that the carnation growers were seeking immediate relief from thrips damage and could not wait for the completion of laboratory experiments. The sprays were applied at about weekly intervals unless otherwise stated.

Paris green 8 oz., plus brown sugar 8 lbs., placed in 1 gallon of water a week or more before spraying was found to hold thrips damage to a minimum. The material was diluted with 100 gallons of water at the time of spraying. These results were obtained during the fall and early spring, even without spraying through the winter months when thrips damage is at a minimum. With the advent of late spring the combination failed to check the increase of thrips damage.

Available commercial spray concentrates containing 18 per cent pyrethrum

Table 4.—Effectiveness and rapidity of action of tartar emetic at low concentrations against the onion thrips and gladiolus thrips in 14 laboratory tests. 25 thrips per test, showing per cent daily mortality when caged as soon as spray dried.

Amount per 100 Gallons of Water		Onion Thrips			Gladiolus Thrips		
Tartar emetic	Brown sugar	No. days · 1	2	3	1	2	3
2 lbs.	4 lbs.	84	100		80	100	
2 lbs.	4 lbs.	79	100		84	100	
2 lbs.	8 lbs.	69	91	100	84	100	
2 lbs.	Blackstrap molasses 1 pint	80	92	100	68	92	100
1 lb.	Brown sugar 2 lbs.	80	96	100	72	92	100
½ lb.	2 lbs.	64	84	100	71	85	100
4 lbs.	8 lbs.	83	100		78	96	100

extractive and a derris extract of 1½ per cent rotenone used at 2 quarts and 1 quart per 100 gallons of water respectively failed to check thrips damage during the late spring period of rapid increase in damage, even when applied twice a week.

Nicotine sulfate 1 pint and molasses 1 pint in 100 gallons of water proved satisfactory in holding thrips damage to about 10 per cent damaged flowers although the grower used it throughout the winter at weekly intervals and at semi-weekly intervals during the spring. Nicotine sulfate was not tried at other concentrations. Higher concentrations of molasses rendered the cut flowers unsightly, whereas at 1 to 800 the residue was hardly noticeable yet the same droplet formation had been produced.

The nicotine sulfate-Karaya gum combination, in spite of the excellent laboratory results, was not tested very extensively in the greenhouse. This was due largely to the difficulty experienced in mixing the Karaya gum and to the unsightly residue the gum particles left on the foliage. One small greenhouse test indicated that it was an efficient thrips control measure.

Table 5.—Tartar emetic with brown sugar reduced thrips damage from 100 per cent to 32 per cent on Spectrum Supreme variety of red carnations when used four times at weekly intervals in a greenhouse.

1940 Date	Total Number of Flowers	Flowers Damaged	Per Cent Damaged	Tartar Emetic Applied
April 24	364	364	100	No
30				Yes
May 6	336	326	97	Yes
13	337	315	93	Yes
20	388	352	91	Yes
27	200	100	50	No
June 4	334	108	32	No

Tartar emetic 2 lbs., plus brown sugar 4 lbs. or blackstrap molasses 1 pint, to 100 gallons of water has given by far the best results of all the combinations tested under greenhouse conditions. By using this formula a crop that appeared to be ruined was salvaged (table 5). With this combination it was also possible to keep flowers practically free of damage throughout the period of heaviest infestation (table 6). Higher concentrations of tartar emetic caused severe flower injury and more brown sugar or molasses produced objectionable visible residues. At the strength indicated there was some petal injury, especially on the lighter colored varieties, and the residue became objectionable through accumulation after too frequent applications.

Table 6.—Tartar emetic with brown sugar applied nine times over a period of four months limited thrips damage to 1 per cent on King Cardinal variety of red carnations in a greenhouse.

1940 Date	Flowers Examined	Flowers Damaged	Per Cent Damaged
February 7	400	2	.5
April 19	400	2	.5
30	400	0	0
May 13	500	6	1.2
27	666	1	.15
June 4	592	3	.5

No other materials have been tried in greenhouses.

DISCUSSION.—Tartar emetic approaches the ideal residual poison for thrips control. It is highly toxic, quite rapid in action, completely soluble, does not deteriorate on the foliage and is relatively non-injurious to the plants. Alone it is not attractive to thrips, but this defect is easily remedied by the addition of a spray adjunct such as brown sugar. Apparently concentrations as low as 8 oz. per 100 gallons can be used, especially where a sustained spray program is needed on long season crops. On carnations, three or four weekly or biweekly applications are required in the fall, starting before the flowers appear, then no more are needed until February when three or four weekly or biweekly applications should be made. This is followed with applications about every 3 weeks until the end of the season in July. The essential point to consider is the maintenance of a toxic residue which is not objectionable in appearance.

Brown sugar, molasses, and similar materials increase the surface tension of the spray solution. When applied as a mist type spray fine droplets rather than a film are deposited. Excessive spraying tends to make these droplets coalesce and run off the carnation foliage. Excessive spraying also produces an accumulation of spray material in the flowers which causes injury. The formation of droplets

and the moisture holding or hygroscopic action of the brown sugar seem to be the factors inducing thrips feeding rather than the sweetness.

Brown sugar and molasses increase the toxicity of paris green, especially after a period of time, probably by releasing more soluble arsenic as shown by Richardson (1934). Boiling paris green and brown sugar in a small amount of water makes the mixture still more toxic when diluted for spraying; however this increase in toxicity is accompanied by severe plant injury. Paris green in brown sugar solution is too slow in action and too injurious to flowering plants to warrant its use for thrips control on carnations except in regions of very light infestation where it would not have to be used very often.

Nicotine sulfate in combination with molasses does not persist as a toxic residue for more than two days. Only with frequent applications can control be obtained and so it is not practical.

Nicotine sulfate in combination with Karaya gum forms a residual poison capable of holding thrips damage to a minimum. The difficulty of mixing Karaya gum with water raises a question as to its practicability; furthermore, the gum leaves an unsightly residue.

Rotenone and pyrethrum extracts combined with wetting and spreading agents failed to function as residual poison sprays. The fact that they do not persist as toxic residues largely explains the failure.

Mercury and fluorine compounds and other compounds of arsenic and of antimony offer possibilities as thrips poisons, especially the latter which are more soluble and less injurious to plant tissues than the others.

SUMMARY.—Tartar emetic 2 lbs., plus brown sugar 4 lbs., in 100 gallons of water is the best residual poison spray combination tested for thrips control on greenhouse carnations.

Nicotine sulfate plus molasses or Karaya gum; and paris green plus brown sugar have some value but are inferior to tartar emetic. Preliminary tests of other materials indicate that they may prove suitable.—8-7-40.

LITERATURE CITED

Anderson, L. D., and H. G. Walker. 1940. Notes on the Control of Onion Thrips. JOUR. ECON. ENT. **33**(2): 278–80.

Bailey, S. F. 1932. A Method Employed in Rearing Thrips. JOUR. ECON. ENT. **25**(6): 1194–6.

Boyce, A. M., and C. O. Persing. 1939. Tartar Emetic In the Control of Citrus Thrips on Lemons. JOUR. ECON. ENT. **32**(1): 153.

Dustan, A. G. 1931. The Gladiolus Thrips and Its Control. Can. Dept. of Agr. D. F. C. and G. I. 101, Ottawa 34.

Eddy, C. O., and S. S. Sharp. 1937. Effect of Different Spreaders on Thrips Control by Nicotine. JOUR. ECON. ENT. **30**(3): 427–30.

Kearns, C. W., and C. C. Compton. 1938. The Control of Common Red Spider and Thrips by the Use of N, N Amyl Benzyl Cyclohexylamine. JOUR. ECON. ENT. **31**(5): 625–30.

Nelson, R. H. 1938. Tartar emetic as a Field Spray Against the Gladiolus Thrips. JOUR. ECON. ENT. **31**(2): 208–11.

Richardson, H. H. 1934. Studies of Derris, Nicotine, Paris Green, and Other Poisons in Combination with Molasses in the Control of the Gladiolus Thrips. Jour. Ag. Res. **49**(4): 359–73.

DUE doubtless to disruption of the ordinary shipping procedure in Great Britain by war conditions, crates and boxes containing various articles of merchandise from England, have recently been found on arrival at New York to be constructed in part of pieces of elm wood sometimes still covered with bark. The entry of elm wood with bark from Europe is prohibited by the Dutch elm disease quarantine (No. 70), since such materials may not only carry the Dutch elm disease fungus, *Graphium ulmi*, but may also be infested by insects, particularly *Scolytus* spp., which are recognized as important agents in spreading this disease. Measures have been taken to see that all this elm crate and box material is destroyed by burning and to emphasize to the English shippers concerned the prohibition on its use.

Attractiveness to Codling Moth of Substances Related to Those Elaborated by Heterofermentative Bacteria in Baits

J. R. Eyer and J. T. Medler*
New Mexico Agricultural Experiment Station, State College, New Mexico

In 1937 the authors first reported (Eyer *et al.* 1937) on the possible role of certain species of bacteria in the production of attractive substances in a fermenting sirup solution (*Brer Rabbit* sirup 1 part by volume to 9 parts of water) used as a bait for the adult codling moth, *Carpocapsa pomonella* L., in New Mexico. Of some 265 species of bacteria and yeasts found to be normal inhabitants of the bait flora, three in particular are receiving further study because their consistent occurrence throughout the season in such baits has been demonstrated and also because further comprehensive field tests over two seasons, 1937 and 1938, demonstrated that cane sirup bait fermented by pure cultures of these species usually attracts more codling moth adults than does the same bait when allowed to ferment in the field through natural contamination from the mixed bacterial and fungal flora of the surrounding air. The results of two such field comparisons are presented in table 1, A and B.

The three species of bacteria concerned, *i.e.*, *Aerobacter aerogenes*, *A. oxytocum*, and *Aerobacillus polymyxa* have been grown on the customary differential media and their identity verified by authorities in the particular groups. Morphologically, the two species of *Aerobacter* may be characterized as short, gram-negative, nonmotile rods which grow singly or in short chains on ordinary culture media. The growth is white, pearly and iridescent for *A. aerogenes*, and soft and fluffy for *A. oxytocum*. *Aerobacillus polymyxa*, on the other hand, is a long, motile, gram-negative rod, producing spores on carbohydrate media and evidencing a viscid creamy or yellow appearance in culture. More detailed descriptions of the morphology and cultural characteristics of these organisms are to be found in the 49th Annual Report of the New Mexico Agricultural Experiment Station (Garcia 1938).

Physiologically, these species are characterized by bacteriologists as "heterofermentative," because of their ability to produce a comparatively large number of fermentation and dissimilation products, particularly alcohols, aldehydes, ketones, organic acids, and certain gases. Buchanan and Fulmer (1930) state that the principal compounds produced in the fermentation of sucrose, glucose, and fructose by the species of *Aerobacter* as determined by Kluyer, Donker, and Kay are acetaldehyde, formic, acetic, succinic, and lactic acids, ethyl alcohol, acetyl methyl carbinol, carbon dioxide, and hydrogen. *Aerobacillus* produces, in addition to the above-mentioned, butyl alcohol, butylene glycol, and acetone. Further interactions may result in the production of fumaric and lactic acids and these on hydrolysis produce malic acid. Various amino and phenyl substitution compounds are possible when protein disintegration products are formed from the bodies of dead bacteria or yeasts. Among these α-amino acetic acid (glycine), phenylacetic acid, and hydroxybenzoic acids have been demonstrated.

Naturally, the determination of all the fermentation and dissimilation products possible in sirup bait is a long and tedious procedure. Thus far our investigations along these lines have been limited to ascertaining some of the simple acids, alcohols, and related products which are actually present in appreciable amounts in such baits during the time of their attractiveness to the codling moth, *i.e.*, within the first 10 days of their exposure in the field. For this purpose, 500 cc. samples of sterile cane sirup solution of the same composition as that used as bait were inoculated with each of these three species of bacteria. These were allowed to ferment for a period of 10 days in the laboratory at room temperature. They were analyzed at intervals during this period, using the partition techniques of Osburn & Werkman (1931), and Stahly & Osburn (1934). Table 2 presents the results of one of these analyses at the end of a ten-day period of fermentation.

* Junior author with Division of Entomology, University of Minnesota, St. Paul, Minnesota.

Table 1A.—Catches from cane sirup bait inoculated with heterofermentative bacteria, exposed in pint fruit jars,* June 10 to June 30, 1937.

Name of Organism	Days Operated										Total Catch	Average per Day
	2	4	6	8	10	12	14	16	18	20		
Bait 1—*Aerobacter aerogenes*	0	3	2	9	14	12	2	0	0	0	42	2.1
Bait 2—*Aerobacter oxytocum*	1	5	1	9	38	10	2	4	1	1	72	3.6
Bait 3—*Aerobacillus polymyxa*, Strain I	0	0	1	3	3	1	0	0	0	0	8	0.4
Bait 4—*Aerobacillus polymyxa*, Strain II	0	1	8	4	12	5	1	1	1	0	33	1.7
Check—Cane sirup bait. No organism	0	0	0	1	0	1	0	1	1	0	4	0.2

* Each bait consisted of 250 cc. *Brer Rabbit* sirup solution inoculated with the organism indicated, placed in a pint mason jar. This was in turn fastened to the bottom of a one-gallon tin pail containing a few inches of water to assist in trapping the moths.

These analyses revealed that ethyl alcohol is the most abundant of the simple alcohols, that acetic and lactic acids are the prevalent acids, and that the end-products of the aldol and acyloin condensation reactions are represented by acetyl methyl carbinol and acetone.

ness of homologous series of (1) alcohols closely related to ethyl alcohol, (2) of organic acids closely related to acetic acid, (3) of esters likely to be formed by the combination of alcohols and acids of the aforementioned two series, (4) of the dibasic and hydroxy acids closely related to

Table 1B.—Catches from cane sirup bait inoculated with heterofermentative bacteria and surrounded by an electrified grid.* July 28 to September 2, 1937.

Name of Organism Used for Inoculation	Days Operated																	Total Catch	Average per Day
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34		
Bait 1—*Aerobacter aerogenes*	8	11	11	21	17	22	0	6	6	1	2	51	17	46	5	4	0	228	6.7
Bait 2—*Aerobacter oxytocum*	5	9	12	7	15	8	2	4	8	2	3	13	5	1	2	1	1	98	2.9
Bait 3—*Aerobacillus polymyxa*, Strain I	4	13	8	8	14	8	6	2	7	2	2	1	5	1	1	0	0	82	2.4
Bait 4—*Aerobacillus polymyxa*, Strain II	5	8	11	7	6	4	1	2	2	0	2	5	11	5	1	0	1	71	2.1
Check—Cane sirup bait, no organisms and no cover	9	5	14	8	6	4	4	2	4	1	1	2	0	1	0	0	0	61	1.8

* Each bait consisted of 500 cc. *Bret Rabbit* sirup solution inoculated with the organism indicated and placed in a quart jar provided with a cotton gauze cover to prevent contamination. Each was surrounded by the electrocuting unit of a Model K Folmer Electrocide from which the mazda lamp was removed. The moths were recovered in a pan of water suspended beneath the electrocuting unit.

The establishing of the occurrence of these compounds through chemical analyses, suggested that further investigations of the attractiveness of pure chemicals related to them might furnish additional information concerning the nature of attractiveness with respect to this particular insect. Thus far the experiments have consisted of comparisons of the attractive-

lactic acid and of the more common alkyl esters derived therefrom, (5) of higher alcohols similar to acetyl methyl carbinol, and (6) of the gases known to be formed during alcoholic fermentation.

METHODS.—The chemical compounds mentioned were compared in pure from under different environmental conditions by the following methods. (1) In the

Table 2.—Analyses of cane sirup baits fermented by pure cultures of aerobacter and aerobacillus for 10 days at room temperature.

Bacterium	Ethyl Alcohol	Isopropyl Alcohol	Butyl Alcohol	Acetic Acid	Propionic Acid	Butyric Acid	Lactic Acid	Acetone
	Per cent			Per cent			Per cent	
Aerobacter aerogenes, Strain 1	.82	—	—	.69	—	—	—	—
Aerobacter aerogenes, Strain 2	.72	—	—	.61	—	—	—	Trace
Aerobacter aerogenes, Strain 3	1.12	—	—	.51	—	—	—	Trace
Aerobacter aerogenes, Strain 4	1.08	—	—	.59	—	—	—	Trace
Aerobacter oxytocum	1.04	—	—	.70	—	—	—	Trace
Aerobacillus polymyxa, Strain 1	.73	—	—	.60	—	—	.12	.038%
Aerobacillus polymyxa, Strain 2	.82	—	—	.59	—	—	.10	.036%

laboratory by releasing moths in an olfactometer of the type described by Eyer (1937) but provided with eight lateral arms bearing the jars of attractants. In this case the chemicals with the exception of gases, were emulsified at the fate of 1 cc. of liquid or 1 gram of dry material in 99 cc. of a mixture of gum tragacanth, glycerine and water.* This formula was suggested by a manufacturer of aromatic chemicals for effecting a slow, even evolution of aroma. The procedure followed in recording and evaluating these catches is further described in the next section. (2) Additional comparisons were then made of the chemicals found to be attractive in the olfactometer by suspending 1 per cent emulsions of them in quart fruit jars in trees in the College apple orchard and comparing them with the standard cane sirup bait as check. Records of their attractiveness were taken for the duration of the flight period of the moths of the generation concerned and the results were recorded as moths per trap per day, and percentage ratio to the sirup bait. (3) Chemicals found to be attractive by methods 1 or 2 were exposed as in 2 in jars suspended in a large screen cage over an apple tree. Newly emerged moths were placed in the cage each day and the average catch could be compared with the catches obtained by method 2. This procedure was designed to supplement procedure 2 by providing a number of newly emerged moths for each night of the test. (4) One percent concentrations by volume or weight of the same attractive chemicals were added directly to standard cane sirup bait and exposed in the orchard as in method 2 in order to determine whether they increased attractiveness during the course of the fermentation.

RESULTS AND DISCUSSION:—The olfactometer tests of 1937 were carried on during March using moths reared from larvae overwintering in bands, these being of the same Spring generation as those caught later in the field between April 15 and May 15 (table 7). Preliminary trials with esters of the simpler acids and alcohols have been reported in a previous publication (1937) using the same apparatus. The design of apparatus was suggested by the work of Peterson & Haeussler (1928) who used a somewhat similar contrivance for determining the response of the codling moth and the oriental fruit moth to colored lights. In the preliminary experiments it was found that the same essentials were necessary to secure activity and response on the part of the moths as were observed by these earlier workers, *i.e.*, conducting tests with recently emerged moths during evening hours when

* Formula:—Tragacanth 200 grams, glycerine 100 cc., water to make 2 liters. Manufactured by the Florasynth Laboratories New York City, under the name *Emulsarome*.

Table 3.—Results of comparisons of simple alcohols and acids in the olfactometer.

Material	Number Caught	Average Catch per Replication	Percentage Ratio to Check
ALCOHOLS			
Methyl	1	.33	100
Ethyl	0	—	—
n-Propyl	2	.66	200
Isopropyl	4	1.33	400
n-Butyl	0	—	—
Isobutyl	0	—	—
Amyl	0	—	—
Isoamyl	0	—	—
Check	1	.33	100
ACIDS			
Formic	1	.33	50
Acetic	0	—	—
Propionic	2	.66	100
Butyric	0	—	—
Valeric	(Not tested)		
Check	2	.66	100

Table 4.—Results of comparisons of hydroxy, dibasic and aromatic acids in the olfactometer.

Material	Number Caught	Average Catch per Replication	Percentage Ratio to Check
HYDROXY AND DIBASIC ACIDS			
Oxalic	0	—	—
Lactic	1	.33	66
Malonic	1	.33	66
Succinic	2	1.00	200
Succinic (Solid)	1	.50	100
Check	1	.50	100
AROMATIC ACIDS			
Benzoic	0	—	—
Benzoic (Solid)	0	—	—
α-Toluic	0	—	—
α-Toluic (Solid)	2	2.00	200
Check	1	1.00	100

they are normally most active and at temperatures above 70 degrees. In addition it was found that when attractive chemicals were used, illumination of low intensity assisted in maintaining activity.

Table 5.—Results of comparisons of esters of simple acids in the olfactometer.

Material	Number Caught	Average Catch per Replication	Percentage Ratio to Check
Esters of Simple Acids			
Methyl acetate	4	4	106.7
Methyl propionate	11	11	293.3
Methyl *n*-butyrate	14	14	373.3
Ethyl acetate	2	2	53.3
Ethyl oxyhydrate	0	—	—
Ethyl propionate	6	6	160.0
Ethyl butyrate	5	5	133.3
Ethyl valerate	1	1	26.7
n-Propyl acetate	0	—	—
Isopropyl acetate	1	1	26.7
Propyl propionate	3	3	80.0
Isopropyl propionate	0	—	—
Propyl butyrate	0	—	—
n-Butyl acetate	1	1	26.7
Isobutyl acetate	2	2	53.3
n-Butyl propionate	1	1	26.7
Isobutyl propionate	2	2	53.3
n-Butyl *n*-butyrate	1	1	26.7
Isobutyl butyrate	0	—	—
Butyl valerate	2	2	53.3
Isobutyl valerate	2	2	53.3
Amyl formate	0	—	—
Isoamyl acetate	0	—	—
Isoamyl propionate	1	1	26.7
Isoamyl butyrate	0	—	—
Amyl valerate	0	—	—
Amyl caproate	1	1	26.7
Check	15	3.75	100.0

In order to insure these conditions the following procedures were observed: All olfactometer tests were conducted in a dark attic room where the temperature averaged 70 to 75 degrees, and their duration was approximately from 6:30 to 10:00 P.M. For illumination a 25-watt frosted mazda light globe was so placed above the olfactometer as to illuminate white glazed cardboard reflectors placed to face the outer end of each of the eight arms. Adjustments in height of light source and angle of reflectors were made so that the lateral compartments were illuminated to an intensity of approximately 1 foot candle. Since the average catch per replication by the check (*i.e.*, tragacanth-glycerine *Emulsarome*) was usually less than that of the more attractive chemicals during the course of the olfactometer comparisons it was not considered as having been excessively influenced by an indirect light source of such low intensity. Air circulation was maintained in the apparatus by a small electric fan sucking gently against the screen floor of the central chamber.

Since the olfactometer used possessed eight arms, each series of chemicals (*e.g.*, alcohols, acids, and esters), were tested in groups of seven in comparison with a check of the plain *emulsarome*. First,

Table 6.—Results of comparisons of esters of hydroxy, dibasic and aromatic acids in the olfactometer.

Material	Number Caught	Average Catch per Replication	Percentage Ratio to Check
Esters of Hydroxy, Dibasic and Aromatic Acids			
Methyl oxalate	1	1	26.7
Methyl lactate	5	5	133.3
Methyl malonate	6	6	160.0
Methyl benzoate	6	6	160.0
Methyl α-toluate	9	9	240.0
Methyl cinnamate	2	2	53.3
Ethyl oxalate	6	6	160.0
Ethyl lactate	0	0	—
Ethyl malonate	7	7	086.7
Ethyl succinate	0	0	—
Ethyl tartrate	2	2	53.3
Ethyl citrate	2	2	53.3
Ethyl benzoate	0	0	—
Ethyl α-toluate	4	4	106.7
Phenyl ethyl phenyl acetate	1	1	26.7
Phenyl ethyl phenyl cinnamate	1	1	26.7
Ethyl cinnamate	0	0	—
n-Propyl oxalate	0	0	—
n-Propyl lactate	2	2	53.3
Isopropyl oxalate	0	1	26.7
Isopropyl lactate	1	1	26.7
Isopropyl benzoate	1	1	26.7
n-Butyl oxalate	0	0	—
n-Butyl lactate	2	2	53.3
Isobutyl lactate	0	0	—
n-butyl *dl*-malate	5	5	133.3
n-Butyl tartrate	0	0	—
n-Butyl citrate	0	0	—
n-Butyl benzoate	0	0	—
Isobutyl benzoate	0	0	—
n-Butyl α-toluate	3	3	80.0
Isobutyl α-toluate	2	2	53.3
Isoamyl oxalate	0	0	—
Isoamyl tartrate	0	0	—
Isoamyl benzoate	0	0	—
Benzyl cinnamate	1	1	26.7
Check	15	3.75	100.0

seven alcohols from methyl to amyl were tested, then a series of seven acids, then a series of those alcohols and acids proving most attractive in the tests of the first two series. Of the simple alcohols and acids, each material found attractive on first test was given two additional tests, making three in all. In the case of the esters which showed a much higher degree of attractiveness, only one test was made.

Only moths which had emerged during the preceding twenty-four hours were used. These were not chilled or anesthetized before use but were allowed to enter the central compartment of the olfactometer by placing the container in which they had emerged on the floor of same before each test. Between 12 and 25 moths were used for each replication but because the number of active moths varied with each replication this was taken into consideration in the evaluation of results by comparison of average catch per replication and percentage ratio to the checks, tables 3 to 6. In the sixteen consecutive tests covering comparisons of eight alcohols, fourteen acids and sixty-one esters 234 moths were used. Of this number, 167 entered some one of the eight arms of the olfactometer and this figure constituted the total catch used in the computation of results.

It is realized that such a method is somewhat arbitrary, but since the purpose of the olfactometer trials was merely to furnish a preliminary basis through comparisons of ratios for selection of the most attractive materials for further test in comparison with cane sirup bait in the field, it is considered permissible. In interpreting the significance of the percentage ratios to the *Emulsarome* check the authors do not completely agree with the precedent of Laake *et al.* (1931) as used for determining repellency but have regarded ratios between 50 and 100 as possibly being slightly attractive since the check itself almost invariably caught a few moths. In the field where cane sirup bait is used as the basis for computing percentage ratios all those above zero are regarded as attractive because of the high degree of attractiveness of the control.

As can be seen by an examination of tables 3 and 4, n-propyl alcohol and isopropyl alcohol proved most attractive of the compounds related to ethyl alcohol, and of the acids related to acetic acid, propionic acid gave the highest indication of attractiveness. Succinic acid rated highest in attractiveness of the dibasic-hydroxy group and α-toluic (phenylacetic) acid of the aromatic group.

Table 5 illustrates the comparison of attractiveness of esters of aliphatic acids. It is seen that the methyl esters exhibited the most consistent degree of attractiveness when the alcohol radical is considered, and the esters of propionic acid were most attractive when the acid radical is considered. In illustration, the percentage ratio to check of the more attractive propionates are cited: methyl propionate 293, ethyl propionate 160, propyl propionate 80, isobutyl propionate 53, and isoamyl propionate 26.7. Indication of superiority in attractiveness is further observed when the four-carbon atom series of butyl alcohol and butyric acid with their respective complements are considered, *e.g.*, 373 for methyl *n*-butyrate, of 133 for ethyl butyrate, and of the relatively high ratings of isobutyl acetate, propionate and valerate as compared with the low-rating members of the series. The results obtained with the higher carbon-number esters were less consistent.

From table 6, it may be observed that many of the methyl esters of the hydroxy, dibasic and aromatic types were attractive. Furthermore, by examination of the percentage ratios it will be seen that the methyl series showed a progression in degree of attractiveness from the ester of lactic acid (133) through malonic (160), and benzoic (160), to α-toluic (240), the phenyl substitution type being superior. Although many of the esters of the four alcohols immediately above methyl in the homologous series were only slightly or not at all attractive, a few attracted sufficiently well to warrant mention. Some of these were esters of those acids which indicated the highest degrees of attractiveness in the methyl series, *i.e.*, ethyl malonate, ethyl α-toluate, *n*-propyl lactate, *n*-butyl lactate, *n*-butyl α-toluate and iso-butyl α-toluate. In addition ethyl oxalate and *n*-butyl *dl*-malate were attractive. The attractiveness of the esters of malonic, malic, and valeric acids is of interest and perhaps significance, since the parent acids or their salts occur in apple and pear.

Field comparisons of some of the more attractive chemicals of the above series were conducted in the State College orchard during the flight period of the spring generation of the same year (table 7). The catches are expressed as moths per trap per day, per cent of total catch of the experiment, and percentage ratio to cane sirup check, but all catches from materials averaging less than one moth per day are omitted from the table. By observation of the percentage ratio of each chemical to the standard sirup bait it may be seen that as in the olfactometer tests, the acids and esters were more attractive than the alcohols. Of the acids, α-toluic, butyric, and acetic were the most attractive, in the order named and closely approached or exceeded the check of cane sirup. Of the ethyl series of esters ethyl α-toluate proved the most attractive in the comparison.

Table 8 presents the results of a second field comparison, using some of the more attractive acids already mentioned as having been tested in the olfactometer and in emulsion in the field. In this experiment, however, the acids were added in 1 per cent concentration by weight or volume to standard cane sirup bait and exposed in quart fruit jars in the College orchard during the same period as indicated for table 7. Each material was replicated four times in randomized series and the data were analyzed for variance, using the ratio of the difference to the standard error of the same, as suggested by Goulden (1929), for determining the significance. Although the solubility of these acids in water varied all except benzoic acid are moderately soluble and it could be expected that most of them would enter into the fermentation process and possibly, to some extent, influence the formation of dissimilation products.

It is interesting to observe that the data when analyzed by this method suggests relationships between the comparative attractiveness of the baits and their chemical similarities. Although benzoic and citric acids were the only two acids of this series which showed significant superiority, it is seen that with respect to relative attractiveness the six-carbon and aromatic acids are in an upper bracket, the four-carbon hydroxy acids occupy a mid position, while the straight chain and simple dibasic acid types are lowest in the series. This same general relationship can also be observed by re-examination of tables 3 to 6.

In 1938 olfactometer tests were conducted with a series of substitution alcohols similar to acetyl methyl carbinol. Owing to a series of late spring frosts

Table 7. Field comparison of emulsions of chemicals as attractants for codling moth during flight period of the overwintering generation, April–May, 1937.

Material	Average per Trap per Day	Per Cent Total	Percentage Ratio to Sirup Check
Alcohols			
Ethyl	1	2.38	33.3
n-Propyl	1	2.38	33.3
n-Butyl	1	2.38	33.3
Capryl	2	4.75	66.7
Acids			
Formic	1	2.38	33.3
Acetic	2.6	6.18	86.7
Propionic	2	4.75	66.7
Butyric	4	9.50	133.3
Lactic	2	4.75	66.7
Malonic	2.5	5.94	83.3
Citric	2	4.75	66.7
Benzoic		4.75	66.7
α-Toluic	7	16.63	233.3
Esters			
Ethyl propionate	1	2.38	33.3
Ethyl butyrate	1	2.38	33.3
Ethyl lactate	1	2.38	33.3
Ethyl succinate	1	2.38	33.3
Ethyl tartrate	1	2.38	33.3
Ethyl phenylacetate	3	7.13	100.0
n-Propyl acetate	1	2.38	33.3
Check			
Cane sirup	3	7.13	100.0

In 1938 olfactometer tests were conducted with a series of substitution alcohols similar to acetyl methyl carbinol. Owing to a series of late spring frosts

Table 8.—Average catch and elimination level for four replications of cane sirup and attractive chemicals, April–May, 1937.

Bait Standard Cane Sirup Plus	Catch and Standard Error	Difference	Standard Error of Difference	Difference Divided by Standard Error of Difference
1. Sodium benzoate	33 ± 3.38	—	—	
2. Citric acid	30 ± 2.08	3	3.97	.7557
3. Benzoic acid	25 ± 1.22	8	3.59	2.2284*
4. Bakers Yeast	17 ± 1.39	16	3.65	4.3836
5. Tartaric acid	17 ± .86	16	3.49	4.5845
6. Sirup alone	15 ± .65	18	3.44	5.2326
7. Malic acid	14 ± .74	19	3.46	5.4913
8. Malonic acid	10 ± .65	23	3.44	6.6860
9. Oxalic acid	9 ± .41	24	3.40	7.0588
10. Butyric acid	4 ± .00	29	3.38	8.5799

* 2. equivalent to odds of 22:1.

which killed the 1938 apple crop, sufficient moths were not available for further tests until 1939. The same materials were then compared in the field cage and in the field. The results are presented in table 9.

Table 9.—Comparisons of acetyl carbinol with related alcohols, 1938–1939.

MATERIAL	OLFACTOMETER		FIELD CAGE		FIELD (in sirup)	
	Average Catch per Replication	Per Cent Ratio to Check	Average Catch per Day		Average Catch per Trap per Day	Per Cent Ratio to Sirup Check
			Emulsion	Sirup		
Acetyl methyl carbinol	1.8	180	2.4	0.6	0.9	128.6
Isobutyl methyl carbinol	2.4	240	2.2	1.5	0.9	128.6
Phenyl methyl carbinol	2.6	260	2.5	0.4	1.2	171.4
Phenyl ethyl carbinol	2.2	220	2.9	1.8	2.0	285.7
Sirup Check	1.0*	100	0.0	0.4	0.7	100.0

* *Emulsarome* check.

It will be noticed that these more complex alcohols show a higher degree of attractiveness than the simple alcohols used in earlier experiments and that those containing a phenyl radical are usually superior, especially phenyl ethyl carbinol (= phenyl propyl alcohol).

Also in 1938, some of the simpler aldehydes and ketones related to acetic acid and ethyl alcohol were tested in the olfactometer and in the field cage. The olfactometer tests were not consistent due apparently to the high volatility of the aldehydes. However, it was found that by emulsifying all materials in the gum tragacanth-glycerine *Emulsarome* and placing the aldehydes in vials with plaster of Paris stoppers some idea could be gained of their relative attractiveness. One per cent concentrations of each of the test chemicals were placed in vials which were floated in quart jars of water and these were suspended in the field cage. The checks consisted of two jars each of an equivalent quantity of the *Emulsarome* and of the standard sirup bait. The results are presented in table 10. Of the aldehydes, propionaldehyde appeared to be most attractive, while with the ketones there appeared to be little difference in attractiveness. The similarity in attractiveness of the compounds of this series, many of which have identical acyl radicals, tends to support the conclusion of Speyer (1920) that the molecular group, $(CH_3CH_2)X$, is the important chemotropic stimulus.

A few comparisons have also been made of the gases which represent the end products of most of the several lines of carbohydrate fermentation, *e.g.*, carbon dioxide, hydrogen, and oxygen. These were generated in Starkey microgenera-

Table 10.—Comparisons of acetic acid and some related aldehydes and ketones in the field cage, April–May, 1939.

MATERIAL	AVERAGE CATCH PER DAY	PER CENT OF TOTAL	PER CENT RATIO TO *Emulsarome* CHECK
Acetic acid	2	7.4	200
Propionic acid	1	3.7	100
Acetaldehyde	2	7.4	200
Propionaldehyde	4	14.8	400
Valeraldehyde	2	7.4	200
Acetone	3	11.1	300
Methylethyl ketone	3	11.1	300
Diethyl ketone	2	7.4	200
Emulsarome check	1	3.7	100
Cane sirup check	7	25.9	700

tors and bubbled through water placed in the mason jar type bait containers. None of these were found to stimulate response in the olfactometer, but in field cage tests hydrogen and carbon dioxide both consistently attracted more moths than oxygen or the water checks (table 11). The correlation between moth catch and gas production in sirup baits has been mentioned in an earlier publication (1931).

Table 11.—Field cage comparison of gases, 1939.

	AVERAGE PER TRAP	PER CENT TOTAL	PER CENT RATIO TO WATER CHECK
Oxygen (from sodium peroxide)	0	0	0.0
Oxygen (from hydrogen peroxide)	.71	19.3	200.9
Hydrogen (from Zn + HCl)	1.07	28.8	305.7
Carbon dioxide (from $CaCO_3$ + HCl)	1.57	42.3	448.6
Water	.35	9.8	100.0

The fact that hydrogen and carbon dioxide show indication of being mild attractants is of interest because it suggests that these gases may be more than neutral carriers for the aromas of volatile acids, alcohols and esters also produced in carbohydrate fermentation.

SUMMARY.—Cane sirup bait (*i.e., Brer Rabbit* sirup 1 part by volume to 9 parts of water) fermented by species of *Aerobacter* and *Aerobacillus* has been found to be more attractive to the codling moth in New Mexico than the same bait allowed to ferment through contamination by the yeast, mold, and bacterial flora of the air. Analyses of this bait fermented by these bacteria revealed that ethyl alcohol, acetic and lactic acids and acetyl methyl carbinol are the most prevalent of the compounds in these respective classes during the first ten days of fermentation. A review of the literature relating to the chemical products elaborated by these bacteria in the fermentation of sucrose, glucose and fructose suggested that homologous series of alcohols, acids, and esters related to the abovementioned be exhaustively compared in a number of different ways. A design of olfactometer somewhat similar to that used by earlier investigators in determining the response of the codling moth to colored lights proved useful in making preliminary comparison of these organic chemicals in the laboratory. Also a mixture of tragacanth, glycerine and water was found instrumental as a medium for the emulsification of these chemicals for comparison. In tests in the olfactometer more of the hydroxy, dibasic, and aromatic acids proved attractive than the aliphatic acids and simple alcohols. Of the simple alcohols and acids, the three carbon groups (propyl or propionyl) proved consistently attractive. Of the esters of the same, the methyl series exhibited the most consistent degree of attractiveness when the alcohol radicle is considered, and the propionyl series when the acid radicle is considered. Of the hydroxy and dibasic acid esters, those of malonic, malic, lactic, and oxalic were attractive. Of the more complex alcohols and esters those possessing a phenyl radicle were consistently attractive both in olfactometer and field comparisons. Since a wide variety of alcohols, acids, esters, and gases, related to those elaborated by heterofermentative bacteria in the fermentation of sirup bait were found to be attractive, it is concluded that no one chemical is to be considered the most important or key factor in the chemotropic response of the codling moth.

LITERATURE CITED

Buchanan, R. E., and E. I. Fulmer. 1930. Physiology and biochemistry of bacteria, Vol. III, Williams and Wilkins Co., Baltimore, Maryland, pp. 217–64.

Eyer, J. R., and Hinman Rhodes. 1931. Preliminary note on the chemistry of codling moth baits. JOUR. ECON. ENT. **24**(4): 702–11.

Eyer, J. R. 1937. Ten years' experiments with codling moth bait traps, light traps and trap bands. N. M. Bul. **253.**

Eyer, J. R., J. T. Medler, and H. P. Linton. 1937. Analysis of attrahent factors in fermenting baits used for codling moth. JOUR. ECON. ENT. **30**(5): 750–6.

Garcia, Fabian. 1937. 48th Annual Report. New Mexico Agr. Exp. Sta. pp. 33–5.
1938. 49th. Annual Report. New Mexico Agr. Exp. Sta. pp. 46–50.

Goulden, C. H. 1939. Statistical methods in agronomic research. Plant breeders' series publication No. 2. Can. Seed Growers' Assn., Ottawa, Ont.

Laake, E. W., D. C. Parman, F. C. Bishopp, and R. C. Roark. 1931. The chemotropic responses of the housefly, the green bottle flies and the black blowfly. U.S.D.A. Tech. Bul. **270.**

Osburn, O. L., and C. H. Werkman. 1931. Determination of organic acids. V—Application of partition method to quantitative determination of acetic, propionic, and butyric acids in mixture. Industrial and Engineering Chemistry, Analytical Edition, **3**: 264–75.

Peterson, Alvah, and G. J. Haeussler. 1928. Response of the oriental fruit moth and codling moth to colored lights. Ann. Ent. Soc. Amer. **21**: 353–79.

Speyer, E. R. 1920. Notes on chemotropism in the housefly. Ann. App. Biol. **7**: 124–40.

Stahly, G. L., O. L. Osburn, and C. H. Werkman. 1934. Quantitative determination of acetone and ethyl, butyl, and isopropyl alcohols in fermentation liquors. The Analyst 59: 319–25.

SCIENTIFIC NOTES

Insecticidal Properties of the Fruit of *Phellodendron* spp.

The Amur cork or velvet tree, *Phellodendron* spp. is a native of the Amur River basin in Amurland, the adjoining coast of the Japanese Sea, and the southern extremity of Sakhalin Island. It was introduced into this country about 1856 and specimen trees may be found in the Library of Congress Grounds, Washington, D. C.; the Arnold Arboretum, Boston, Massachusetts; and the Plant Introduction Garden, Bell, Maryland. The dioecious flowers appear in May and June and the fruit ripens in September and October. The fruit, when crushed, has a pronounced aromatic odor, described in some textbooks on botany as "turpentiny."

The habits of the tree indicate that it has possibilities as a plant for soil-erosion control, but commercial uses for the fruit remain undeveloped. At the suggestion of S. B. Detwiler, Soil Conservation Service, U. S. Department of Agriculture, a chemical study of the fruit was undertaken by E. K. Nelson, Bureau of Agricultural Chemistry and Engineering. Nelson has found[1] that the volatile oil of the fruit consists principally of the aliphatic terpene myrcene, together with a small amount of methyl *n*-nonyl ketone, methyl *n*-heptyl ketone, and geraniol. The residue remaining after the removal of the oil was submitted to this Bureau for insecticidal tests. Preliminary tests of the residue showed considerable toxicity against mosquito larvae, the housefly, and codling moth larvae (apple-plug method). Against mosquito larvae the extract was more toxic than a derris standard containing 5.2 per cent of rotenone. Tests against the housefly showed the material to be about as toxic as the derris standard. A single spray test indicated that the material possessed a low toxicity to southern armyworm larvae, but this also applied to derris and pyrethrum. The material is a fast acting poison much like pyrethrum and nicotine.

The results of these tests have been sufficiently encouraging to warrant a further investigation of the fruit. Studies are now under way with fruit furnished by the Soil Conservation Service which have for their object the isolation of the insecticidal principle or principles in a pure form.[2]—6-15-40.

H. L. Haller, *Bureau of Entomology and Plant Quarantine, Washington, D. C.*

[1] E. K. Nelson, Jour. Am. Chem. Soc. 60: 920, 1938.

[2] The studies here reported were participated in by E. R. McGovran, E. H. Siegler, M. S. Schechter and W. N. Sullivan.

The European Pine Shoot Moth in British Columbia

The main purpose of this paper is to list the varieties of pines most susceptible to infestation by the European pine shoot moth, to present a record of insect parasites reared from collected material and to show the value of cooperative effort in dealing with the problem of eradication of this pest.

The European pine shoot moth was first reported in British Columbia by Mr. W. Downes of the Division of Entomology, Science Service, Victoria, B. C. In 1927, it was found infesting *Pinus mughus* and *P. densiflora nana* in one of the nurseries at Victoria. About this same time this insect was also intercepted by the Dominion Plant Inspection Service on a shipment of *P. mughus* imported from Europe by a local nurseryman in Vancouver.

The control measures then adopted were rather drastic inasmuch as the pines were completely destroyed and it was not until June, 1938, that the European pine shoot moth was again reported in the City of Vancouver. Inasmuch as this insect is a serious enemy of pine, steps were immediately taken by the Division of Entomology and the Plant Protection Division at Vancouver to determine the distribution of the insect. A preliminary survey showed that the infestation had been in progress for at least three years. As the moths were already commencing to emerge at that time it was considered too late to organize and carry out satisfactory control measures. Plans were made, however, for a cooperative project to be undertaken. Scouting was commenced in the latter part of March of the following year (1939), a second survey being made later in the spring. In the first survey trees showing previous years' injury and in the second survey, trees showing bud injury to the present season's growth were located. In all, 232 pines of which 170 were lodgepoles, *Pinus contorta*, were mapped out in the infested area, and 113 pines charted in the adjoining area. In the eradication work, the property owners in the infested area were visited and the need for drastic action explained to them. In practically every instance the fullest cooperation was received—even to the actual removal of trees. The Provincial Forest Service cooperated by supplying a truck and two men.

In all, eighty-four lodgepole and four mughus pines were removed and destroyed by fire. A few valuable mughus found infested were clipped and these, together with all remaining pines in the infested area, were sprayed. The material used was a combination spray of eighteen pounds of arsenate of lead, five pounds of nicotine sulphate, with two and a half pounds of an emulsified herring oil as a spreader, to two hundred and forty gallons of water. Sprays were applied July 11 when observation disclosed eggs were beginning to hatch. A maximum temperature of 68 degrees F. was recorded on the day spray was applied. Vancouver Park officials cooperated by applying the spray.

The re-survey of the area this spring showed that this infestation had apparently been cleaned up.

Native Parasites.—Material reared in cages showed over twenty per cent parasitism. Each of the four species recovered were represented as follows:

Calliephialtes comstockii (Cress.)	—22 specimens
Ephialtes obesus (Cush.)	— 4 specimens
Ephialtes conquisitor (Say.)	— 4 specimens
Ephialtes evetriae (Vier.)	— 1 specimen

The identifications were made by Mr. G. Stuart Walley of the Systematic Division of Entomology, Department of Agriculture, Ottawa, who advises that none of the species submitted is new and some are known to attack caterpillars which feed in the terminal growth and cones of conifers.—7-15-40.

W. G. Mathers, *Division of Entomology, Science Service*, and H. F. Olds, *Plant Protection Division, Production Service, Dominion Department of Agriculture, Vancouver, B. C.*

Contribution No. 13, Division of Plant Protection, Production Service, Dominion Department of Agriculture, Ottawa, Canada.

Three Additional Species of Aphids Transmitting Narcissus Mosaic

In an earlier note by Blanton & Haasis(1939) four species of aphids are reported to be vectors of the virus causing narcissus mosaic, namely, *Aphis rumicis* L., *Macrosiphum solanifolii* (Ashm.), *Macrosiphum rosae* (L.), and *Myzus convolvuli* (Kalt.). Subsequent tests show that three additional aphid species are able to transmit the same virus, namely, *Anuraphis roseus* Baker, *Myzus cerasi* (F.), and *Macrosiphum pisi* (Kalt.).

The test plants used in the experiment here reported were of the variety Sir Watkin, grown in field plots containing both mosaic-diseased and healthy plants in the approximate ratio of one mosaic to four healthy. Methods of caging the plants and of manipulating the insects during transfer are described by Blanton (1939) and Blanton & Haasis.[1] Aphid identifications were made by P. W. Mason, of the Bureau of Entomology and Plant Quarantine. Continuing the practice established when these investigations were initiated, type specimens from vector colonies are preserved in the United States National Museum in Washington, D. C., under the following accession numbers: *Anuraphis roseus* Baker T.C. 6653, *Myzus cerasi* (F.) T.C. 6652, and *Macrosiphum pisi* (Kalt.) T.C. 6648.

Although these three species of aphids will feed on narcissus plants when migrating from the natural host, they cannot survive and establish colonies when confined to healthy growing plants, for narcissus is rather toxic to aphids. This would suggest that only a short feeding period is necessary for transmitting the virus.

The proportion of healthy plants to which these aphids transmitted the virus is shown in table 1.

Table 1.—Virus transmission from mosaic to healthy Sir Watkin narcissi by aphids.

Aphid Species	Insects Reared On—	Date of Transfer 1939*	Healthy Plants Exposed to Inoculation and Surviving in 1940, Number†	Plants Infected, Number
Anuraphis roseus Baker	apple	June 1	18	13
Myzus cerasi (F.)	cherry	June 5	36	15
Macrosiphum pisi (Kalt.)	vetch	June 5	31	24
Control (no aphids)	—	—	106	4

* Symptoms of the disease appear following the year of inculation.

† Some of the bulbs rotted during the interval of 1939 to 1940

These results compare favorably with those regarding the other four aphid vectors (Blanton & Haasis 1939).

Four accidental transmissions occurred among a total of 106 control plants that were unexposed to inoculation. Error of this magnitude has been encountered before when tests were performed with plants growing in caged field plots. A probable explanation is presented by Blanton & Haasis.

Only two of the vectors reported in this note have been definitely recorded from narcissus. During the season of 1939 *Anuraphis roseus* occurred sparingly in a small narcissus planting which was bordered on one side by apple trees. *Macrosiphum pisi*, on the other hand, was rather common in the same planting and was found to be breeding in large numbers on isolated vetch plants growing in and about the narcissus field. Thus the activities of these aphids lend supporting evidence to the theory that as vectors of the virus causing narcissus mosaic they are but casual visitors.

To the present time vectors of the narcissus-mosaic virus are represented by seven aphid species belonging to four genera.—7-8-40.

F. S. Blanton, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine* and F. A. Haasis, *Cornell University, Ithaca, N. Y.*

[1] Insect transmission of the virus causing narcissus mosaic. In manuscript.

Literature Cited

Blanton, F. S. 1939. Aphid transmission of the virus causing white streak of narcissus. Jour. Econ. Ent. 32(5):726–27.

Blanton, F. S., and F. A. Haasis. 1939. Transmission of the narcissus mosaic virus by aphids. Jour. Econ. Ent. 32(3):369–70.

A Portable Dusting Tent

The problem of dust drift in the field is one which the experimenter with small plots has always to consider. When large fields are available the effect of dust drift can be considerably reduced by buffer plots. When the plots have to be restricted as much as possible in order to test a large number of treatments in a small area, the problem becomes intensified. The writer has been able to reduce drift to a minimum in 20-plant plots of staked tomatoes by the use of a set of four portable tents, each of which covered five plants at one time.

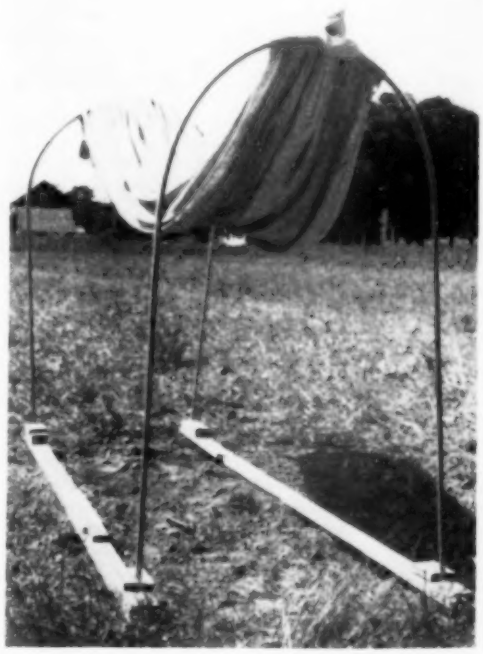


Fig. 1.—Detail of construction of tent frame.

The tent used can best be described as resembling a covered wagon top. It was 10½ feet long, 2½ feet wide, and 5½ feet high. The height was determined by the length of the tomato stakes. The tent frame consisted of two U-shaped pieces of three-eighth inch galvanized iron pipe (Fig. 7) which were bent into shape over a barrel. The bows were made to stand upright by thrusting the legs through snugly fitting holes bored through wooden blocks 4 inches high which were nailed to the ends of two 1 inch by 3 inches by 11 foot boards. The sharpened ends of the iron legs projected 3 inches beyond the wooden part of the frame so that they could be thrust into the ground.

When spread flat, the tent was 10 by 12 feet. Wide hems were made along the 12-foot sides. One end of the tent was closed by sewing a piece of cloth, the shape and dimensions of the metal frame, to the edges of the hems. Also, a skirt a foot wide should be sewed to the bottom of the closed end and the two sides in order to prevent the escape of dust from beneath the frame. The open end of the tent was closed by a drop curtain fastened at the top of the arch by three snaps. The tent was assembled by thrusting the legs of the frame through the hems and then through the holes in the boards. When the tent is ready to store the frames can be folded flat, as shown in figure 2.

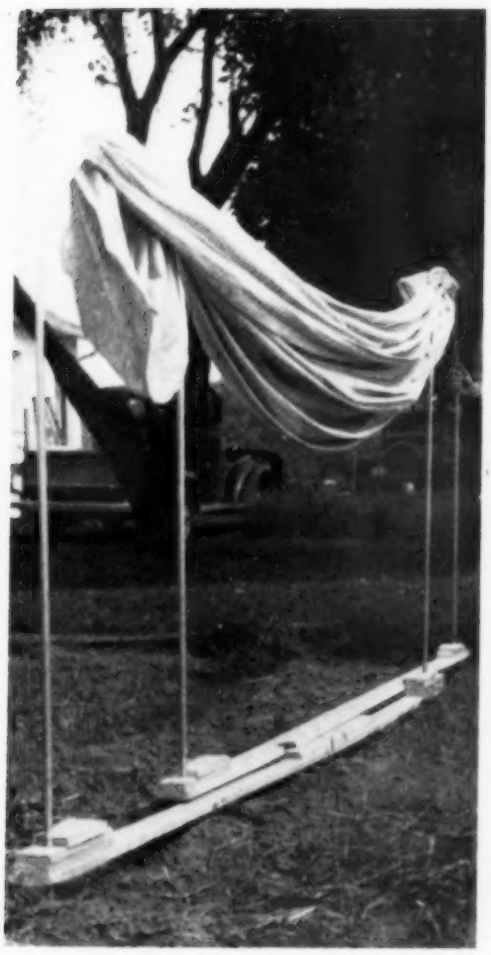


FIG. 2.—Tent frame folded for storage.

The tent itself should be made of some light-weight, dust-tight material. We used heavy muslin, but there was some leakage unless the cloth was wet with dew.

After the tent was set over the plants, operation of the hand duster was begun when the operator was 3 or 4 feet in front of the tent and was continued as he walked forward directing the dust over the top of the plants and then along each side of the row. When dusting was completed, the curtain was dropped. The dust usually had settled by the time the three other tents had been reset.

FIG. 3.—Tent in place over tomato plants with end open for dusting plants within.

Two men were needed to move a tent. One stood at each end, grasped the ground edges of the hems around the pipe frames, and shoved the two tent sides upward so that the cloth lay bunched on the arches. By pulling the lower edge of the closed end of the tent over the bunched cloth on the arch, the tent was held on the arches out of the vision of the men carrying the tent.

Four tents will keep three men very busy; two men are needed to carry the tents while the third aids in locating plots, and applies and changes dusts. Operations run more smoothly with a fourth man to locate plots and help with the dusting. The amount of time required to complete a set of treatments will depend upon the situation. In 1938, after acquiring some experience, three men applied 11 dust treatments, each replicated five times, in 4½ hours. The work was done during the daytime. In 1939, 14 dusts, each replicated six times, were applied during twilight and darkness. The shortest time with this setup was about 7½ hours with four men. Hunting plots in the dark and handling wet tents reduced the speed of operation, but by dusting in the night, dust drift was reduced still further.

Dust will cling to the tent-cloth to a certain degree. Much of this can be removed by whipping the tents when the dusts are changed. The mixing of different materials is then negligible.

Possibly the biggest objection to the use of the tent in experimental work is that the coverage of dust obtained with it may be superior to that obtained under ordinary dusting conditions.—7-9-40.

CHAS. H. MARTIN, *Ohio Agricultural Experiment Station, Wooster, Ohio.*

Establishment of the Codling Moth on Stone Fruits in California

In the extensive literature on the codling moth many investigators have reported apparently original observations on the infestation of stone fruits by this insect. The fruits have been peaches, plums, nectarines, apricots, and cherries. With two exceptions such infestations were caused, presumably, by moths from nearby apple and pear trees. As far as determined by the present study there are but two records of the codling moth maintaining itself on stone fruits independently of its preferred hosts. Pettey reported studies in 1925 and 1926 at Wellington, South Africa, which showed that the moth had been maintaining its existence in apricot orchards a half mile or more distant from its usual hosts and had been causing serious loss in many orchards to apricots and Kelsey and Wickson plums. It appeared that a one-generation strain had developed. In some apricot orchards where no treatment was applied 20 per cent of the crop was infested. Regular treatment for the pest was made for a number of years but recent correspondence has indicated that the destructiveness of the pest has declined. In 1929 the writer (Smith, 1929) reported studies in southern California which indicated that the codling moth was maintaining itself on plums and apricots independently of the usual hosts, namely, apples, pears and English walnuts. The principal infestations were in Kelsey plum orchards in the vicinity of Pomona, California. This condition was first noted in 1926. At that time less than one per cent of the plums were infested. In 1927 and 1928 at Riverside, about twenty-five miles east of Pomona, the moth was found to be maintaining itself on apricots and peaches independently of other hosts. In the most heavily infested orchards three per cent of the fruit was attacked.

In the past ten years the pest has become increasingly destructive in commercial plum orchards in the Pomona district. Before spraying was undertaken the annual loss in some orchards amounted to 20 per cent of the crop. Spraying with lead arsenate was first undertaken in 1933. For several years the usual program of control provided for the application of basic lead arsenate spray about the middle of May when the plums were about one-half inch in diameter. In one orchard under observation where no control was practiced, the annual loss amounted to about 50 per cent of the crop. In 1938 a loss of 25 per cent was experienced in a sprayed orchard. This heavy loss was attributed to a prolonged hatch of worms. During the past two years two applications of spray have been made. The first application is made the middle of May and the second is made three to five weeks later. The spray is basic lead arsenate four pounds to one hundred gallons of water and sufficient spreader to produce a good film coverage on the plums. The earlier studies indicated that only one generation would be able to develop on a given variety of plum. However, in 1934 two broods of worms developed on Kelsey plums. The first matured in the green plums and emerged in June. The second brood was maturing when the crop was picked the first half of August. Some of the earlier records of the codling moth on stone fruits were mentioned by the writer in 1929 in the paper cited below. The literature of the last fifteen years indicates that the infestation of plums and apricots is more prevalent in subtropical and warmer temperate regions than in cooler temperate regions. This fact appears to be significant to the establishment of the insect on these fruits in South Africa and southern California.—7-18-40.

RALPH H. SMITH, *University of California at Los Angeles.*

LITERATURE CITED

Pettey, F. W., 1925. Preliminary report on the biology of the codling moth and its control on apricots. Jour. Dept. Agr. South Africa **11**: 56–65, 137–52.

Pettey, F. W., 1926. Report of studies of codling moth at Wellington during the 1925–26 fruit season. Jour. Dept. Agr. South Africa **12**: 461–83.

Smith, R. H., 1929. The codling moth as a pest of stone fruits. Calif. State Dept. Agr. Mthly. Bul. **18**: 304–9.

Mosquito Collections at Brownsville, Texas

In November, 1939, the mobile *Aedes aegypti* Control Unit of the U. S. Public Health Service moved from Charleston, South Carolina (Fisk & Le Van, 1940) to Brownsville, Texas, where it remained until June, 1940. In connection with the routine mosquito control activities of the unit, mosquito collections during the period of Nov. 29, 1939 to May 1, 1940, were made.

Four electrically-operated New Jersey type, model 50, light traps were used during the first four months of this period; during the month of April 1940 a fifth trap was added. One of the traps was located at the municipal airport, about five miles from town, while all the others were within the city limits of Brownsville. The light trap at the airport and those in the outlying sections of town collected more mosquitoes, particularly of the "wild" species, than did the centrally located ones. The traps were visited twice weekly. In table 1 the numbers and species of mosquitoes collected are shown by half-month periods. The rainfall, and the mean maximum and mean minimum temperatures for the same periods are also given.

Reference to the table shows the definite relationship of mosquito abundance to the rainfall. Each semi-monthly period in which a measurable amount of rain fell was followed by a period in which a larger number of mosquitoes was collected. Particularly was this true of the period following the very heavy rains of late March, for in this half-month period one third of all the mosquitoes taken during the survey was trapped. A relation of abundance to temperature is also apparent. The coldest weather occurred during the last half of January, when below-freezing temperatures were experienced on several occasions, with a mean minimum temperature of 37.2 degrees F. Most species disappeared entirely from the collections during this period, and there was a great decrease in numbers of those species which were trapped.

The mosquitoes collected during the five months of winter and early spring (December through April) may be roughly classified into three groups. First are the multibrooded non-winter breeding species, which were fairly abundant when the traps began operating in November. They decreased in abundance as the temperatures dropped, and disappeared entirely following the late January frosts. The four species of *Anopheles* and *Uranotaenia lowii*

illustrate this group. *Theobaldia inornata* might appear to belong here since it was abundant in the traps at the start and had disappeared entirely by spring. Actually, as pointed out by King *et al.* (1939), it is a winter breeding species most common during the colder months in the latitude of Brownsville and hence does not fall into any of the three groups described here. The second group consists of multi-brooded species which are present throughout the year, though less abundant during the coldest months. The domestic *Culex quinquefasciatus* and the "wild" *Culex tarsalis* are the chief examples of this group. The third group consists of the single- or double-brooded temporary rain pool mosquitoes that appear in vast numbers following the heaviest rains of the year. The five species of *Psorophora* are all members of this group. The eggs of these mosquitoes are laid on the moist soil of drying ditch bottoms and pond sites. When the soil dries they remain dormant for months or even years, ready to hatch when submerged. This group of mosquitoes was mainly responsible for the relatively large numbers of mosquitoes trapped in the half-month period just following the heavy rains of late March.

Besides the mosquitoes listed in table 1, one additional species, *Aedes triseriatus* (Say), was found. Adults were reared from larvae collected in a tree hole where they were found associated with the larvae of *Aedes alleni*. This brings the total number of mosquito species found by the authors at Brownsville to twenty-six. Of this group two species, both of them determined by Dr. Alan Stone, are new records for the United States. Neither of them has heretofore been found any closer to this country than the Canal Zone (Dyar, 1928), and it is possible that one or both species have been brought into this country by airplane. One of them, *Deinocerites spanius*, breeds in the holes of fiddler-crabs, and its peculiar habits are described elsewhere (Fisk, Ms.[1]).

[1] To be published in the Annals of the Entomological Society of America.

The larvae of the other species, *Culex chidesteri*, occur in ground pools, according to Dyar (1928). The species may be poorly established at Brownsville since only a single male was discovered in the trap collections.

With the exception of the two species just mentioned, and of *Uranotaenia lowii*, all the mosquito species found in the present survey have previously been taken in the state of Texas. Several of the species encountered are of interest in that their distribution in the United States is restricted to southern Texas or the lower Rio Grande Valley. These include *Anopheles albimanus*, *Culex coronator*, *C. declarator*, and *Aedes thelcter*.[2]

Table 1.—Trap collections listed by half-months.

Species	December		January		February		March		April		Totals
	Half-Month Periods										
Anopheles crucians Wied.	4	5	1	2	0	0	0	0	0	0	12
A. quadrimaculatus Say	13	5	9	0	0	1	2	0	3	2	35
A. pseudopunctipennis Theob.	6	2	0	4	0	0	0	0	0	0	12
A. albimanus Wied.	44	18	7	1	0	0	0	0	0	0	70
Culex (*Culex*) spp.*	294	158	194	34	62	33	95	57	184	84	1195
C. (*Melanoconion*) spp.†	11	6	22	2	12	12	11	0	5	0	81
Theobaldia inornata (Will.)	28	15	21	26	7	14	5	0	0	0	116
Aedes infirmatus D. & K.	0	0	1	4	0	0	0	0	2	0	7
A. thelcter Dyar	0	0	0	0	0	0	0	0	167	59	226
A. alleni Turner	0	0	0	0	0	0	1	2	2	7	12
A. aegypti (L.)	0	0	0	0	0	0	0	0	0	1	1
A. sollicitans (Walk.)	0	0	0	0	0	0	0	0	11	0	11
Deinocerites spanius (D. & K.)	13	9	5	0	4	0	1	3	7	52	94
Psorophora ciliata (F.)	0	0	0	0	0	0	0	0	29	0	29
P. columbiae (D. & K.)	1	0	0	0	0	0	0	0	320	1	322
P. cyanescens (Coq.)	0	0	0	0	0	0	0	0	17	0	17
P. discolor (Coq.)	0	0	0	0	0	0	0	0	81	4	85
P. signipennis (Coq.)	0	0	0	0	0	0	0	0	1	4	5
Uranotaenia lowii Theob.	15	1	1	0	1	0	0	0	0	0	18
Total mosquitoes	429	219	261	73	86	60	115	62	829	214	2348
											Averages
Inches rainfall per half-month	0.0	0.42	0.0	0.29	0.09	0.26	0.0	3.57	0.05	0.03	0.47
Mean maximum temperatures	78.7	69.8	65.7	55.8	71.4	73.9	74.8	77.4	79.3	84.0	73.5
Mean minimum temperatures	53.7	51.5	53.7	37.2	54.3	52.5	57.2	61.5	62.5	67.9	55.6

* *Culex* (*Culex*) spp.; in order of abundance:
C. quinquefasciatus Say
C. tarsalis Coq.
C. coronator D. and K.
C. salinarius Coq.
C. restauns Theob.
C. declarator D. and K.
C. chidesteri Dyar

† *Culex* (*Melanoconion*) spp.:
C. erraticus D. and K.

SUMMARY.—In connection with *Aedes aegypti* control activities at Brownsville, Texas, mosquito collections by means of light traps were made during the period from Nov. 29, 1939 to May 1, 1940. Altogether, twenty-six species were encountered, of which two, *Deinocerites spanius* and *Culex chidesteri*, were new records for the United States.—7-29-40.

FRANK W. FISK, *Junior Entomologist* and JAMES H. LE VAN, *Passed Assistant Sanitary Engineer, U. S. Public Health Service.*

LITERATURE CITED

Dyar, H. G. 1928. The mosquitoes of the Americas. Carnegie Inst. of Wash. Publ. No. **387.**

Fisk, F. W. and **J. H. Le Van,** 1940. Mosquito collections at Charleston, South Carolina, using the New Jersey light trap. JOUR. ECON. ENT. **33:** 578–9.

King, W. V., G. H. Bradley, and **T. E. McNeel,** 1939. The mosquitoes of the southeastern states. U. S. Dept. Agric. Misc. Publ. **336.**

[2] The authors are greatly indebted to Dr. Alan Stone of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, who very kindly determined all the material submitted him, some of which the authors were unable to place.

A Seed-infesting Psocid New to North America

On June 1, 1940,[1] I received from a San Francisco Bay seedsman a small glass vial filled with spinach seeds infested with a psocid, which was said to be very abundant in a shipment of spinach seed received from Holland. An examination of the contents showed it to be swarming with a species which moved throughout the contents of the vial with characteristic jerky motions. The psocid was different from any previously encountered species and specimens were forwarded to Dr. C. F. W. Muesebeck, in charge, Division of Insect Identification, Bureau of Entomology and Plant Quarantine, and was identified as *Lepinotus patruelis* Pearman by Dr. A. B. Gurney. Dr. Muesebeck also very kindly gave references to Pearman's published articles describing this and related species. From June 1 to the present writing (July 15) the insect has continued to thrive in the vial of spinach seed, although it is evident that the size of the population has decreased somewhat during this period. The spinach seed is considerably adulterated with particles of leaves, stems, and other parts of the seed-bearing plants and the psocids appear to be feeding upon all the varied contents of the vial. Eggs are attached to the dried materials and all stages of development of the insect are observable.

Lepinotus patruelis Pearman was originally taken from a jar containing dried willow leaves at Bristol, England, January, 1930, and subsequently described as a new species (Pearman, 1931). This appears to be the only record of its occurrence outside of Europe. The eggs are very small, 0.4 mm. long, somewhat almond shaped, transparent or whitish, with fine longitudinal ridges between which are single rows of minute pits, and with a plainly marked apical rupturing area. They are flattened basally and attached to the seeds and particles of plant materials and cannot be seen without the aid of a lens. The first instar young are transparently-white, the intermediate forms are grayish, and the adults are yellowish-brown, dark brown, or fuscous. They all move with rapidity. The adults are rather robust and somewhat flattened, smooth and shiny, hairy and brachypterous. The winglets are pale, elongate-rounded, widest basally, extending to the 3d abdominal segment, and clothed with numerous stiff spines; the antennae 25- to 27-segmented with the 9th and 13th segments noticeably shorter than contiguous ones; the rods or picks 3-toothed; and the spermatheca with one or more oval and pointed brown bodies of variable sizes.

Pearman (1931) and Peus (1933) account for five species in the genus *Lepinotus* as follows:

Lepinotus inquilinus Heyden. Europe.
Lepinotus lepinotoides (Ribaga) (*Atropos*). South Africa.
Lepinotus patruelis Pearman. Europe, England, Holland, Germany, North America (California).
Lepinotus reticulatus Enderlein. Europe (Germany), North America (United States).
Lepinotus sericeus Kolbe. Europe (Germany).

Of these *L. inquilinus* Heyden is the best known and has been rather widely distributed in stored products.—7-29-40.

E. O. Essig, *University of California.*

[1] On July 19, 1940 Henry Washburn, County Agent, collected specimens of this same species in a private residence in Santa Cruz. This might indicate that the insect has been in California for some time.

LITERATURE CITED

Enderlein, G., 1927. Ordnung: Flechtlinge. Copeognatha. Die Tierwelt Mitteleuropas Band IV: 1–16.

Pearman, J. V., 1929. New species of Psocoptera from warehouses. Entom. Mthly. Mag. **65**: 104–9.

Pearman, J. V., 1931a. A new species of *Lepinotus* (Psocoptera). Entom. Mthly. Mag. **67**: 47–50.

Pearman, J. V., 1931b. *Lepinotus patruelis*: further note. Entom. Mthly. Mag. **67**: 50.

Pearman, J. V., 1931c. More Psocoptera from warehouses. Entom. Mthly. Mag. **67**: 95–8.

Peus, F., 1933. Flechtlinge als Wohnungs- und Materialschädlinge, besonders in Neubauten. Z. Gesundh. Tech. u. Stadtehyg. **XXV** (8): 483–90. (Rev. Appld. Ent. Ser. A, **21**: 532–3, 1933).

Weber H., 1933. Copeognatha. Biologie Tiere Deutschlands. Lief **39**: 27.1 to 27.50.

Chloropids Swarming in Houses

The occurrence in extraordinary numbers in houses of tiny Dipterous insects of the family Chloropidae has been recorded many times by European authors, especially in Germany and England. The vast swarms (Massenauftreten or Massenvorkommen) are recorded as covering the ceilings and windows, and at times making it impossible to use certain rooms. Hase (1929), recording the collection of 35 to 40 liters of flies in one of the outbreaks, calculated that there were 12 to 14 million individuals concerned, there being about 360 flies per cubic centimeter. Estimates in other instances have been as high as 30 million individuals

All records in the literature are of species of *Chlorops* or *Chloropisca*, and about half refer to the common Palaearctic species, *Chloropisca notata* Meigen (=*circumdata* Meigen). Because of confusion in identifying species in these genera, many of the older records of other species may really be referable to *C. notata*.

Such mass occurrences of these very small flies have not hitherto been recorded in the Americas. It is of interest therefore to record such an occurrence at a resort hotel in Charlevoix, Michigan, in June, 1940. The writer was asked to determine "insects found around the window casings in our hotel here in Charlevoix. They appear in great numbers and occasionally come out and fly around. . . . They seem to be getting worse every year, though we cannot find any damage they have done." The large number of specimens submitted proved to be *Chloropisca annulata* (Walker) (=*C. variceps* Loew), a species which is the closest relative of the European *C. notata*. To the writer's knowledge, this is the first recorded instance in America of chloropids swarming in houses as is often observed in Europe.

No conclusion has ever been reached on the reason for the sudden occurrence of such vast numbers of individuals. The most frequently advanced suggestion is that, like the cluster fly, they are seeking quarters for hibernation, since the majority of swarms have been observed in the fall of the year. Swarming for the purpose of mating or oviposition has also been suggested, and emergence en masse from their puparia may also be a possibility. No damage other than considerable annoyance has re-

sulted from these swarms, which can be readily disposed of with pyrethrum fly sprays or dusts.—7-31-40.

CURTIS W. SABROSKY, *Michigan State College, Department of Entomology.*

LITERATURE CITED

Hase, A. 1929. Weitere Fälle von Massenauftreten der Fliege *Chloropisca notata flavifrons*. . . . Anz. f. Schädlingskunde, 5: 159–160.

Observations on the Biology of the Elm Leaf Beetle Parasite, *Erynnia nitida* R.-Desv.

At intervals for the past twenty years attempts have been made to establish in the United States the tachinid *Erynnia nitida* R.-Desv. The parasite, like its host *Galerucella xanthomelaena* (Schrank), is a native of Europe.

Erynnia nitida was described from France in 1830 by Robineau-Desvoidy, and is the type species of the genus. According to Silvestri (1909) parasitization of *Galerucella* larva was first observed by Professor Celi di Modena and parasitization of the adult by C. Rondani. The species was figured and redescribed by Rondani (1870). In connection with a comprehensive study of the elm leaf beetle and its parasites in Italy, Silvestri (1909) made additional observations on the biology of *E. nitida*.

Early in 1939, Professor Harry S. Smith made arrangements with the U. S. Bureau of Entomology and Plant Quarantine for a shipment of parasitized adults of the elm leaf beetle to be sent to the Citrus Experiment Station at Riverside, California, from Hyeres, France. This shipment prepared by H. L. Parker was received the first week in May. The adults of *Erynnia* emerged during the period from May 5 to 11, and consisted of 28 males and 14 females. Mating occurred on the second or third day after emergence and oviposition began on the fifth day after mating.

When the female is continually in the presence of suitable hosts, an interval of at least several minutes (usually 5 to 15 minutes) occurs after the deposition of each egg. Under field conditions this habit tends to prevent superparasitism for *Erynnia* is a solitary parasite. The host is most suitable for parasitization when it is a nearly full-fed larva. In searching for its host the parasite makes short flights from leaf to leaf. It oviposits immediately upon contacting a feeding larva. Its reproductive capacity may exceed 100 eggs per female. One female dissected twelve days after mating was found to contain about 140 eggs, in each of which was a fully-formed maggot.

Because of the fact that *Erynnia nitida* overwinters in the adult elm leaf beetle, it has been assumed that the female oviposits on the adult as well as on the larval host. Such is not the case, however. Oviposition occurs only on the larval host. The egg usually is placed on the suture between the sclerites and hatches immediately. The maggot leaves the egg and enters its host almost simultaneously. As it does so, the egg shell often becomes distended with the host's blood from the wound made by the maggot.

At room temperature the feeding period of the maggot within its larval host is about 7 days. The time required for complete continuous development and emergence as an adult is about 18 days, the female requiring 1 day more than the male. The development of *Erynnia*, however, may be discontinuous; that is, the first larval instar may undergo diapause while its host continues to develop and becomes adult. In the insectary the life cycle (egg to egg) of "non diapause" *Erynnia* was about 24 days, that of "diapause" *Erynnia* from about 40 days to 6 months or longer. The average life cycle of non-overwintering "diapause" *Erynnia* was about 50 days. Under natural conditions it is probable that overwintering *Erynnia* cannot complete its development until its host commences feeding in the spring.

In 1939, four generations of *Erynnia* were reared on host material collected when needed in the field. With the possible exception of the first (spring) generation, most of the maggots of each brood undergo diapause and continue their development after the host has become adult.

Second brood maggots that had entered the host larvae on June 17 emerged from the host adults during the period from July 19 to August 5.

Third brood maggots that had entered the host larvae from August 1 to 7 went into a winter diapause, except for seven which emerged as adults (4 males and 3 females) from host larvae during the period from August 18 to 24, and 5 males that emerged from host adults during the third week of September.

Fourth brood maggots that had entered the host larvae from September 1 to 3 went into winter diapause.

Some of the adult hosts containing "diapause" maggots were capable of oviposition.

All of the overwintering adult beetles which had been attacked by *Erynnia* in the insectary were accidentally destroyed. One individual beetle that escaped parasitization lived until April.

During the spring and summer of 1939, 31 mated females of *Erynnia nitida* were liberated in the vicinity of Stockton, California. This region was selected for liberations of *Erynnia* because the infestations of the elm leaf beetle were only a few years old and were free of the pupal parasite *Tetrastichus brevistigma*. The liberations of mated female *Erynnia* in 1939 were made as follows:

	Liberation dates		
Liberation points	*May 23*	*June 17*	*Aug. 8*
Waterloo Road, 5 miles north of Stockton	6♀♀		
Highway 99, 3 miles south of Stockton	2♀♀		
Highway 99, 5 miles north of Stockton		4♀♀	
Homer Norman place, Manteca	3♀♀	10♀♀	4♀♀
Corner of Harding Way and West Lane, Stockton		2♀♀	

The reproduction of *Erynnia nitida* under field conditions during 1939 was remarkable. Six host larvae collected in the field 56 days after the first liberation yielded 1 male and 2 females of *Erynnia* on July 29. On September 2, Percy Wright, of San Joaquin County who had cooperated in making the liberations, stated that "The parasites are undoubtedly well established. On Highway 99, three miles south of Stockton . . . they can be seen flying around the trees and some of them can be found caught in the spider webs."

In December, 1939, about 200 adults of the elm leaf beetle were collected at Manteca, California. Dissections of about 50 specimens indicated a parasitism in the field of about 10 per cent. The other specimens were placed in a screen cage outdoors and protected from sun and rain. In February dissections revealed the fact that the percentage of parasitism in live individuals was decreasing. On the other hand, dissections of dead beetles revealed that many contained first instar larvae of *Erynnia*. The rate of mortality indicated that none of the parasitized beetles would survive the winter. This proved to be the case.

About 30 beetles remained alive at the end of March. These were dissected and appeared to be free from parasites.

A high mortality may have occurred in the field; that is, a large number of the beetles containing the "diapause" larvae of *Erynnia* may have died before the parasite could complete its development. In June, 1940, several hundred larvae of the elm leaf beetle were collected in the field. *Erynnia* was not recovered from this material or observed in the field.

In December, 1940, hibernating beetles again were collected at Manteca. Dissections indicated that parasitism had increased to 20 per cent.

On the West Coast a native tachinid, *Synaplomyia galerucellae* (Villeneuve), occasionally attacks the elm leaf beetle. Apparently only the larval host is parasitized. Silvestri reared the type specimen, a male, from larvae collected in Oregon (Villeneuve, 1933). Several male adults were reared from larvae collected in the vicinity of Stockton in 1937. No females have been reared. The larvae of the native and of the introduced tachinid parasites of the elm leaf beetle are readily distinguished from one another by their morphological characters.—7-29-40.

S. E. FLANDERS, *University of California, Citrus Experiment Station, Riverside.*

LITERATURE CITED

Rondani, C., 1870. Nota sugli insetti parassiti della Galleruca dell' olmo. Bull. Comizio agrario Parma.

Silvestri, F., 1909. Contribuzioni alla conoscenza degli insetti dannosi e dei loro simbionti. Bull. Lab. Zool. Gen. e Agr., Portici, **4**: 246–89.

Villeneuve, J., 1933. Description de *Aplomyiopsis galerucellae* n. gen. n. sp. (Tachinidae) parasite de *Galerucella luteola* (F. Müll.) en Amerique du Nord. Boll. Lab. Zool. Portici **27**: 125–6.

The Establishment in British Columbia of Parasites of the Holly Leaf Miner, *Phytomyza ilicis* Curtis

In the mild, humid, coastal region of British Columbia, the English holly, *Ilex aquifolia*, is extensively grown both as an ornamental tree and for commercial purposes. Every year many tons of clippings, bright with red berries, are shipped away to other parts of Canada and to the United States for decorative use at Christmas time. Generally the leaves are disfigured by blotches which are the partly formed mines created by the larvae of the holly leaf miner, *Phytomyza ilicis* Curtis. Many attempts have been made in the past to find a satisfactory control for this pest but with only partial success. Several years ago the senior author developed a method of dealing with the adult flies by means of 2 per cent nicotine-lime dust, but while this method was fairly satisfactory if correctly carried out the necessity for exact timing detracted greatly from its usefulness. Penetrating oil sprays combined with nicotine have been found quite ineffective in experiments carried out at Victoria, B. C., against the larvae within the mines, due to the tough, impenetrable nature of the holly leaf.

In view of the difficulty of securing control by artificial means it was decided greater success might be attained by the introduction of parasites of the miner and in 1935 the Dominion Entomologist requested the Imperial Institute of Entomology in England to have studies made of the parasites with a view to their introduction into this country.

A comprehensive investigation of the natural enemies of *Phytomyza ilicis* was immediately undertaken by Farnham House Laboratory. The species was found to be heavily attacked by parasites in the areas under study, and beginning with the spring of 1936 several collections of parasitized material were made and forwarded to the Dominion Parasite Laboratory, Belleville, Ont. At the Belleville laboratory the material was held in cold storage and incubation so arranged that emergence and liberation of the parasites synchronized with the proper stage in development of the host. The first parasites were forwarded from Belleville to the Victoria, B. C., laboratory in July, 1936, and this shipment consisted of 1,941 adults of *Chrysocharis gemma* Wlk. This species is said to be the principal parasite controlling the holly leaf miner in Britain. Further shipments of the same species were made shortly after and in addition a number of *Sphegigaster flavicornis* Wlk. and *Chrysocharis syma* Wlk. From 1936 to 1939 inclusive, five species of hymenopterous parasites were received. These were *Chrysocharis gemma*, *Chrysocharis syma*, *Sphegigaster flavicornis*, *Cyrtogaster vulgaris* Wlk. and *Opius ilicis* Nixon. In the years 1936 to 1938 all the parasites received were liberated in Victoria, but in 1939 all liberations were made in the city of Vancouver or its vicinity.

Of the species released, *Chrysocharis gemma* and *Opius ilicis* have become definitely established in Victoria and there is a possibility that a third, *Sphegigaster flavicornis*, may also succeed.

A number of *Chrysocharis gemma*, *Sphegigaster flavicornis*, and *Opius ilicis* were caged on infested holly branches for experimental purposes and the first indications of possible successful establishment were seen in 1938 when 4 adult *Sphegigaster* were recovered from material caged in 1937. The following year 3 *Sphegigaster* and 5 *Chrysocharis gemma* were recovered from material caged in 1938. All these recoveries were made in early spring. It was not until 1940 that any sign of establishment was seen in the open. It was noticed that a large number of the *Phytomyza* mines in a large holly plantation, where liberations had been made, had ceased to attain their usual size at that time of year and were, in fact, merely round spots about one fourth of an inch in diameter. Investigation showed that all these diminutive mines were parasitized. Collections of parasitized mines were made and subsequently *Chrysocharis gemma* was recovered in large numbers. A survey of the plantation revealed the fact that approximately 80 per cent of all *Phytomyza* mines were parasitized. At another plantation, a few miles from Victoria, where liberations also had been made, the same species has been recovered in quantity.

The recovery of *Opius ilicis* was very unexpected and was made by the junior author when examining some holly trees near the laboratory. The first consignment of *Opius* was received in 1937 and numbered only 90. These were enclosed in a cage on infested branches for the purpose of observing the habits of the species, as there was some question at the time of its being a primary parasite. None were recovered in 1938 and they were presumed to have died. But some individuals must have survived or escaped from the cage as there is now a flourishing, though isolated, colony at this spot. Little is known of the habits of this species. Adults have been observed ovipositing in or near *Phytomyza* egg punctures. Growth is completed within the *Phytomyza* puparium so the mines attain full size and parasitized mines cannot be distinguished from others. With *Chrysocharis gemma* on the other hand, growth is completed within the larva of the miner and the mine ceases to grow at a comparatively early stage.

The emergence of adults of both *Chrysocharis gemma* and *Opius ilicis* occurs early in May and is thus synchronized with the emergence of the holly leaf miner.

Regarding the third species, *Sphegigaster flavicornis*, this has not yet been recovered in the field but in view of the fact that it has twice been recovered under caged conditions out of doors there is reasonable expectation that it may yet be found to be successfully established.—8-1-40.

W. DOWNES and H. ANDISON, *Dominion Entomological Laboratory, Victoria, B. C.*

Infestation of a High School by *Oeciacus vicarius* Horv.*

Early in June, 1940, communications were received by the Livestock Insect Laboratory of the Dominion Department of Agriculture at Kamloops, British Columbia, relative to an insect pest invading the high school at Banff, Alberta. A letter from a local physician stated that many of the students, especially the girls, were bitten, the bites "showing a reddened, swollen, itchy area, two or three inches in diameter." So many students complained that the school was shut down and the authorities fumigated the building with formaldehyde gas; this treatment, however, proving unsuccessful. Specimens of the insects were then sent to the Kamloops laboratory and proved to be the swallow bug, *Oeciacus vicarius* Horv. The school authorities were thereupon instructed to destroy any swallow nests present and fumigate with cyanide. From subsequent reports it was learned that swallows have nested under the eaves of the building for some years but no effort was made to dislodge the nests until this spring. Two weeks prior to the reports of insect bites, the school board dislodged some of the nests by the use of a hose and water under pressure. Obviously the pests so disturbed had made their way into the building by way of crevices and cracks around the doors and windows, soon penetrated every room in the building and their presence became evident following complaints by students that they had been bitten. The bugs were locally determined as bed bugs and parents of the students attacked were greatly concerned over the possibility of their own homes becoming infested.

The nests of the swallows were destroyed and the building fumigated with hydrocyanic acid gas. The results were apparently satisfactory and the school reopened in time to permit final examinations. Early in July, however, the writer visited the school and it appears that swallows are rebuilding their nests. Whether the school will be reinfested remains to be seen.—8-7-40.

G. ALLEN MAIL, *Dominion Department of Agriculture, Livestock Insect Laboratory, Kamloops, B. C.*

* Contribution No. 2019, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

Mediterranean Flour Moth Breeding in Comb of Honeybee

On May 11, 1939, we shut up our house in Berkeley, California, and left for an extended trip. Upon our arrival home on July 9 we found a swarm of honeybees in the fireplace chimney. Numbers of bees were running about the living room and there was a loud incessant hum in the chimney. Since it was impossible to remove the comb and the swarm because of the construction of the vent, an attempt was made to drive the intruders away. As the chimney top was only 14 feet from the fireplace, it was thought possible to dislodge the bees by fire. Accordingly such quantities of papers were burned as to carry the blaze out the top of the chimney. Large numbers of singed bees fell into the fire, but the hum in the flue only increased in intensity and never ceased. These efforts were rewarded by more bees coming down into the house so that the occupants were frantic with them. Next a huge fire was built of oak wood with the idea that the heat would do the trick, but not so, the continuous hum never abated—in fact it increased in pitch and volume. Then more strenuous measures were resorted to. First quantities of alcoholic extract of pyrethrum were fed to the flames without results. This was followed by "Blackleaf 40"—a half pint dashed into the hot fire, and finally 5 pounds of flowers of sulphur were ignited in two metal containers and placed on the shelf above the neck of the chimney. Two days of such experiments got no place, and the bees never seemed to take our efforts seriously. Hundreds of workers descended the chimney through fumes and smoke and some of them stung the writer which did not help the cause of the bees much. Fortunately at night those entering the room were successfully trapped in a powerful reflecting floor lamp which attracted and killed them immediately.

On the third day experimenting ceased and known effective measures were taken. The neck of the chimney was tightly closed with hemp sacks and the front of the fireplace sealed. With a pound of granular calcium cyanide in a paper bag and a tight cover for the chimney I climbed to the roof, emptied the cyanide into the chimney and clamped on the lid. By the time I got down to the fireplace the noise in the chimney had ceased. The cyanide had done the trick. The chimney was left sealed until the middle of September when the sacks and covering were removed. During the winter the fireplace was used much of the time and our experience with the bees became a memory.

This summer we again left our house on June 15, 1940, and returned June 28 to find another swarm of bees in the chimney. This time the bees were dispatched immediately and the chimney was left sealed, but the fireplace was opened up to remove the smell of cyanide which persisted for some time.

In the latter part of July adults of the Mediter-

ranean flour moth began to appear in the house in large numbers and caused considerable annoyance at the windows and the lights. The entire house was searched for possible breeding places without success. The moths continued to appear. In August it occurred to me that they might be breeding in the honeycomb and old brood in the chimney and that it would be well to let them clean up the comb and its contents so as not to attract other swarms of bees. Upon the removal of the board from the top of the chimney a considerable number of larvae, pupae, and adults of the moth were resting on the underside indicating that they could only come from the comb a short distance below. Since opening up the chimney only occasional moths have been seen in the house, and it is hoped that they will completely destroy all remnants of the comb and its contents. This incident is another indication of the many household insects that may have been early associated with bees or other social insects.—9-20-40.

E. O. ESSIG, *University of California, Berkeley, California.*

Plum Curculio Adults Survive Low Temperatures in the South

Many southern peach growers are of the opinion that adult plum curculios in hibernation are killed at temperatures as low as those which were recorded in the South during January 1940. At Fort Valley, the minimum daily temperatures for the abnormally cold period January 19 to 29 were 14, 12, 17, 21, 32, 20, 16, 12, 9, 12, and 19 degrees F. On January 30, the writer found living plum curculio adults in Johnson grass and Bermuda grass near Fort Valley. Later on the curculios moved from hibernation into the peach orchards in nearly the usual numbers. It is evident that, contrary to popular opinion, the unusually low winter temperatures in central Georgia in January, 1940, had little effect on the curculios in hibernation. This is not surprising in view of the fact that the insect readily survives much lower temperatures in the North.—10-31-40.

OLIVER I. SNAPP, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

The Use of Calcium Cyanamid in the Control of the Pear Thrips, *Taeniothrips inconsequens* Uzel, in Prune Orchards

The control of the pear thrips, *Taeniothrips inconsequens* Uzel, in prune orchards has become one of the major problems confronting the industry. Studies in the prune orchards of Clark County, Washington, in the spring of 1939 (Huber *et al.* 1939) showed that pulverized and oiled calcium cyanamid of commercial grade, when applied to the soil at the rate of 300 pounds per acre, reduced the number of overwintering thrips to emerge from the soil by approximately 90 per cent. Duplicate areas were treated in orchards in three localities within the period of March 3 to 27. The average total number of thrips to emerge, as determined by trap counts, on non-treated areas in the three orchards was 708.5, 133.5, and 48.5, respectively, and on the treated plots was 79, 13.5, and 5.5 respectively. The pyramid-shaped traps each covered 9 square feet and were designed after those used and described by Smith (1933). The results of these studies also showed that the time to apply the dust for maximum effectiveness was shortly before the overwintering thrips began to issue from the soil.

These studies were continued in the spring of 1940. Several acres were treated in each of three orchards, using a power duster to broadcast the calcium cyanamid at the rate of 300 pounds per acre. The duster was equipped with a hood and short apron to confine the calcium cyanamid near the ground, and to prevent it from drifting into the trees. Two of the orchards were located in Fruit Valley and the third on upland with a southwest exposure toward Lake Vancouver. The period was one of almost daily rainfall, the dust at times being applied in the rain, a condition contrasting with that which prevailed in 1939, a season of comparative dryness and with little or no interference from rainfall.

Some insight into the effectiveness of lighter applications of the dust was gained from tests on small trial plots where the calcium cyanamid was applied with a hand duster at the rates of 200 and 100 pounds per acre, respectively. Each plot included an area 20 feet square with a tree at its center, the trees in the orchards being set at distances of 20 feet each way. All tests were made in duplicate. The data obtained have been summarized in table 1:

Table 1.—Control of Pear Thrips—Vancouver, Washington—1940

Location	Calcium Cyanamid Treatment Pounds per Acre	Trap No.	Total No. Thrips per Trap	Total No. Thrips per Treatment	Per Cent of Thrip Reduction
Valley Orchard No. 1	300	8	3	4	89.19
	300	16	1		
	Check	1	16	37	00.00
	Check	20	21		
Valley Orchard No. 2	300	14	32	33	94.99
	300	23	1		
	200	41	10	33	94.99
	200	42	23		
	100	39	12	16	97.57
	100	40	4		
	Check	5	295	658	00.00
	Check	13	363		
Upland Orchard	300	18	269	533	83.59
	300	24	264		
	200	31	50	66	97.97
	200	32	16		
	100	29	58	474	85.41
	100	30	416		
	Check	11	2270	3247	00.00
	Check	22	977		

The results obtained from the use of calcium cyanamid in 1940 confirm those obtained in 1939. Moreover, it appears that lighter applications are equally effective in the control of the pear thrips. There are several reasons for interest in the possible use of the lighter applications. The use of calcium cyanamid in this manner has been shown to be destructive to the apothecia of the brown-rot fungus, *Sclerotinia fructicola* (Wint.) Rehm. (Huber & Baur 1939), and is an accepted source of nitrogen in meeting fertilizer requirements. It appears that two applications of the calcium cyanamid dust may be indicated where the control of both pests is sought, as an application timed for the control of the pear thrips is, under certain weather conditions, too early for maximum effectiveness against the brown-rot fungus. In such a situation, the lighter applications would doubtless by preferable from the standpoint

of economy and might also be indicated by the fertilizer requirements of the crop.

The effect of the calcium cyanamid on the cover crops should be mentioned. The vegetative cover of the valley orchards consisted in a mixture of Austrian field peas and chickweed, *Stellaria media* (L.) Cyrill., while the upland orchard had been planted to vetch. Within a few days, following the application of the dust, the vegetative covers had taken on a badly burned appearance and the odor of decomposition was noticeable. However, in most instances, new growth appeared within two or three weeks and the vegetative cover seemed to come back with increased vigor. This was especially true of the vetch.

The results of these exploratory studies justify more extensive investigations into the possible application of calcium cyanamid to the problems noted. Such investigations are scheduled for the coming year.—11-4-40.

E. P. BREAKEY, GLENN A. HUBER, KARL E. BAUR, *Western Washington Experiment Station, Puyallup, Washington.*

LITERATURE CITED

Huber, Glenn A., and Karl E. Baur, 1939. Phytopathology, **29**: 436–41.

Huber, Glenn A., Karl E. Baur, and Edward P. Breakey. 1939. Phytopathology, **29**: 825.

Smith, Leslie M., 1933. California Exp. Station Bull. **562.**

A New Species of Leafmining Sawfly Attacking Violet*

For the past four years it has been noted that violets, near the apiary of the Massachusetts State College, were infested by a leaf miner. The violets involved have been identified as *Viola papilionacea.***

In 1938, specimens of the larvae were collected by Herman Broudy. These were sent to the Bureau of Entomology and Plant Quarantine for identification. The report received from the Bureau indicated that the larvae were those of an unknown species of sawfly.

During the following summers observations were made on the development of this insect. As a result, the life cycle has been determined through the larval period.

Adults were observed from July 25 to August 15. The females cut small slits through the epidermis of the upper surface of the leaf. They deposit their eggs, singly, within the leaf. The eggs measure .4 by .6 mm. when deposited but increase in size so that at the time of hatching they are .8 by 1.1 mm. The length of the egg stage, as observed in the laboratory, varied from four to six days.

The larvae, when freshly emerged, are from 1.2 to 1.4 mm. in length. Most of the individuals pass through five instars; however, some have six instars. The larvae that cease feeding after five instars vary from 4.8 to 5.3 mm. in length. Those that passed through six instars vary from 5.3 to 5.8 mm.

The larvae spend the entire feeding period within the leaves. A larva feeds with its ventral surface toward the upper surface of the leaf. To determine the amount of mining, the lengths of the tunnels were measured. It was found that the tunnel lengths, made during an instar, were relatively constant.

Instar	Average Length of Tunnel in Cm.
1	1.82
2	2.58
3	4.20
4	7.92
5	12.40
6	18.32

The duration of the feeding period was determined as between 22 and 28 days. Most of the larvae, that ceased feeding after the 5th instar became quiescent on the 23rd or 24th day. Those passing through a 6th instar require from three to four days longer.

When the larvae have stopped feeding they crawl from the leaf and migrate to the soil. In 1939 soil, trash and plants were brought into the laboratory and examined for pupae but none were found.

In 1940, adults of this insect were collected some of them being taken as they deposited their eggs. They were sent to the Bureau of Entomology and Plant Quarantine for identification due to the illness of Miss Sandhouse, the specimens were forwarded to Dr. Herbert Ross, of the Illinois Natural History Survey. Dr. Ross identified the specimens as a new species of *Fenusa* and will describe it.—11-4-40.

F. R. SHAW, *Amherst, Massachusetts*

* Contribution from the Department of Entomology, Massachusetts State College, Amherst, Massachusetts.

** Identified by Dr. R. E. Torrey, Department of Botany, Massachusetts State College.

Corn Ear Worm Hibernates in Washington State

The corn ear worm *Heliothis armigera* (Hbn.) is very destructive to both sweet and field corn in most sections of eastern Washington. Throughout the season in the Yakima Valley, for example, almost every ear of corn is infested, although by growing long, tight husked varieties such as Golden Cross Bantam, much of the damage is confined to the tip of the ears. Exploratory experiments in the control of this pest have been carried on for four seasons.

Fall plowing and other methods of cultivation have been shown by Barber (1937) to be effective control measures in regions where the corn ear worm hibernates. Data concerning hibernation of this pest within the state was not available. Corn ear worm hibernation cages were therefore constructed and operated according to plans obtained from C. M. Packard and R. A. Blanchard, of the Bureau of Entomology and Plant Quarantine, to determine if the corn ear worm could pass the winter successfully. Four cages were placed in each of two different localities during the winters of 1938–39 and 1939–40. The data obtained from these cages are summarized in the accompanying table.

Placement of worms in the cages in 1938 was completed as much as six weeks later than in 1939. There was no fall emergence of moths in either year. Lateness of worm entry in 1938 seems to have reduced the amount of pupation in fall and survival of pupae in spring. Apparently entry in September is more conducive to successful hibernation. The percentage of pupation in fall seems to have little bearing on the amount of emergence in spring. Pupal survival in spring, on the other hand, seems to be a fair indicator of probable emergence. It is difficult to believe that emergence following hibernation amounts to only

Table 1.—Corn ear worm hibernation cage record from four localities in the state of Washington.

Location of Cages	Soil Type*	Worms Entered Soil	Per Cent†			Period of Moth Emergence
			Pupation in fall One cage each Location	Survival of Pupae in Spring One cage each Location	Moth Emergence Two Cages each Location	
Prosser, Irrigation Branch Exp. Station	Sagemoor fine sandy loam	9–30–38 to 11–15–38	24	12	2.38	6–24–39 to 7– 8–39
Walla Walla Penitentiary Farm	Walla Walla silt loam	9–29–38 to 11–10–38	47	3	0	—
Walla Walla Wireworm Laboratory	Walla Walla lowland soil	9–15–39 to 9–29–39	82	22	1.96	6–26–40 to 7– 9–40
Vera, near Spokane, Spokane Valley	Garrison gravelly sandy loam	9–18–39 to 10– 4–39	67	0	0	—

* Descriptive titles suggested by Dr. L. C. Wheeting, Research Professor of Soils, State College of Washington.
† Per cent based on number worms entering soil in each cage. Number of worms per cage ranges from 50 to 103. Total of 1368 worms entered the soil in the 16 placements. Seven moths emerged.

two per cent, yet these data compare favorably with those obtained in other regions, according to R. A. Blanchard. The time of emergence as found in the cages is much later than the appearance of worm damage in the field, which may begin in April.

The lighter soils such as the Sagemoor fine sandy loam seem to be more favorable to successful hibernation than are the heavy soils. The silt loam in the first Walla Walla experiments packed solidly. The soil in the second Walla Walla experiments was considerably lighter and the cages were near an irrigation flume so that the soil remained moist most of the season, a factor which may have favored emergence. The heavy gravel in the soil in Spokane Valley forced shallow pupation and all the emergence tunnels had collapsed by spring. There are insufficient tests to show definitely that hibernation does not occur in Spokane Valley. All of the soil, furthermore, is not of this type though it does predominate. On the whole, however, worm infestations are somewhat lighter in the vicinity of Spokane than in the southern part of the state, and this may be related to low winter survival.

The weather during the two years was comparable. Both winters were considerably milder than normal and there was very little heaving of the soil. During the eight months, September to April, which may be considered the period of hibernation, the mean temperature in Spokane is about 40 degrees F., Prosser is less than 44 degrees F., and Walla Walla is slightly above 45 degrees F. Spokane valley has an elevation of about 2000 ft. above sea level. This is about 1000 ft. higher than Prosser and Walla Walla and largely accounts for the temperature difference. Perhaps there is enough difference in temperature to affect hibernation, but it is not readily apparent. Annual precipitation at Walla Walla and Spokane amounts to 17 inches and only 7 inches is recorded at Prosser. About 80 per cent of the rainfall occurs during the period from September to April. Even with such a great difference in total rainfall, approximately the same amount of hibernation occurs, and so it may be assumed that precipitation within this range will not affect the overwintering rate. All three areas are irrigated, but very little water is applied during the period of hibernation.—10-16-40.

R. D. EICHMANN, *Agricultural Experiment Station, State College of Washington.*

LITERATURE CITED

Barber, G. W., 1937. The Effectiveness of Cultivation as a Control for the Corn Earworm. U. S. Dept. of Agr. Tech. Bull. 561.

JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol. 33 December, 1940 No. 6

What Should Be Published in Our Journal

THE JOURNAL OF ECONOMIC ENTOMOLOGY had its beginning when the U. S. Department of Agriculture discontinued publishing the records of the meetings of American Association of Economic Entomologists and papers presented before these meetings. It later was taken over by the Association as its official publication and when the revised constitution was approved in December, 1937, the publication of the JOURNAL OF ECONOMIC ENTOMOLOGY became one of the stated objectives of the Association. The objective of the Association other than publication set forth in the constitution is "to promote the study and to advance the science of Entomology."

Defining the objectives of the Association to include the publication of the JOURNAL OF ECONOMIC ENTOMOLOGY on a basis equal and coordinate with the promotion of the study and the advancement of the science of Entomology establishes in a general and broad way the subject matter that may be included in material published in the JOURNAL. The material published should be of a nature to "promote the study and to advance the science of Entomology.

A review of the numerous papers included in the JOURNAL gives a general idea of how nearly the JOURNAL has succeeded in publishing material in all the fields of endeavor included under such a broad definition. There have been articles containing descriptions of new species, articles dealing with apiculture, plant quarantines, cooperative efforts to control injurious species, the history of entomology, administrative problems relating to entomology, extension activities, teaching entomology, ticks, diseases of insects, the relation of insects to diseases of animals and plants, insecticides and many other activities and problems. The greater number of articles have dealt, however, with insects, their habits, distribution and ways of reducing their numbers by various means. Articles in these fields and especially those last mentioned have for the most part set forth the results of investigations pursued with some economic objective. There has, therefore, been a tendency to consider that all articles published in the JOURNAL should be based on original research. There is much merit in this. To use original research as a rigid measuring stick would, however, overlook many things with which the study and advancement of the science of Entomology is concerned.

In the early days of the Association the members were concerned largely with research. Today we realize perhaps even better the importance of research and how essential accurate information is. The scope of entomology has broadened, its importance more generally recognized and many more workers have entered the field and joined our Association. Those interested in special lines of endeavor have met and, with the approval of the combined organization, formed sections. That other units will organize and be recognized as sections seems certain and desirable. It will be a natural expression of growth. Our constitution provides for this but as far as the publication of the results of their deliberations or papers presented the Section is on a somewhat different basis than those units of the Association known as Branches. It says that the papers presented and the discussions within the Branches "shall be eligible for submission for inclusion in the publications of the Association." Papers presented at section meetings have no special recognition or assured sequence of consideration. They are to be considered on their merit and be subjected to the requirements imposed on contributions not presented before meetings of the main Association or its Branches. Action by the Association at its annual meetings in 1934 (Pittsburgh)

and 1935 (St. Louis) indicates, however, that the annual addresses of section chairmen would be published in the JOURNAL.

To improve and maintain the standard of articles published in the JOURNAL our Association has created a Publications Committee to help the editor. Except for the annual address of its President, Section Chairmen and papers presented on invitation of the Association, the length of articles has been limited unless the Association is relieved of the cost of publishing the additional material. The need for such limitation is recognized. Limiting the contributions to original research ignores established practice and the objective "to promote the study and to advance the science of Entomology." What is desired is a bigger and better JOURNAL which will include articles in all fields that come within the broad scope of activities included under our objective. These must, however, be of a character which merits approval and the company of those being published in the most prominent entomological periodical of the world.

S. A. ROHWER

CURRENT NOTES

UNITED STATES RUBBER COMPANY EMPLOYS TWO ENTOMOLOGISTS

The United States Rubber Company announces that it has added two economic entomologists to its staff.

Mr. A. M. Lord is to assist in sales promotion work and will be connected with the Sales Department with headquarters at the New York Office of Company located at 1230 Sixth Avenue.

Mr. R. J. Norton will carry on research work in greenhouses maintained at Fairlawn, New Jersey, in connection with the General Development Division at Passaic.

Both of these entomologists are graduates of the University of New Hampshire and have pursued special work in entomology under the direction of Dr. O'Kane.

CUMBERLAND-SHENANDOAH SPRAY CONFERENCE

The annual conference of entomologists, pathologists and horticulturists interested in the orchard problems of the Cumberland-Shenandoah region of Pennsylvania, Maryland, Virginia, West Virginia and neighboring states was held in Martinsburg, W. Va., on the afternoon and evening of November 14 and the following morning.

The afternoon was spent in inspection of experimental work in nearby orchards. In the evening the group convened for preliminary business and later the entomologists and pathologists had a separate meeting to discuss progress and problems of the year. This meeting was continued on the following morning.

The codling moth, the pistol casebearer and the Comstock's mealybug were the insects most discussed. After the discussion the spray recommendations for the following year were agreed upon, as is the practice in the group concerned. Modification of the recommendations previously in force was mainly to adapt them to the revised tolerance for residues of lead and arsenic recently announced.

Mr. George Geissler presided over the meeting of entomologists, and E. C. Sherwood acted as secretary.

A final session of the entire group was followed by a luncheon in the Hotel Shenandoah, the headquarters of the conference.

Edwin Gould, of Kearneysville, W. Va., was Chairman of the Conference and Carlton F. Taylor, of Morgantown, W. Va., was the secretary and local arrangements were in the charge of these officers. The 1941 conference will be held in Winchester, Virginia.

Among those in attendance at the conference of pathologists and entomologists were the following:

Delaware—
K. J. Kadow

Maryland—
E. N. Cory
C. Graham
H. S. McConnell
A. L. Schroder
E. A. Walker

New Jersey—
R. H. Daines

Pennsylvania—
H. J. Miller
H. M. Steiner
H. W. Thurston, Jr.
H. N. Worthley

United States Department of Agriculture—
G. H. Geissler
M. C. Goldworthy
E. O. Hamstead
R. J. Haskell
G. J. Haeussler
B. A. Porter
J. W. Roberts

Virginia—
M. L. Bobb
A. B. Groves
W. S. Hough
R. H. Hurt
S. A. Wingard

West Virginia—
Edwin Gould
L. M. Peairs
E. C. Sherwood
C. F. Taylor

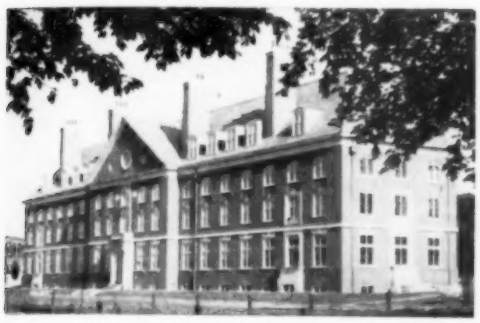
NATURAL RESOURCES BUILDING DEDICATED AT URBANA

Many prominent entomologists attended the dedication, November 15, of the Natural Resources Building, new headquarters of the Illinois Natural History Survey on the University of Illinois campus, Urbana. President Isaiah Bowman of the Johns Hopkins University delivered the principal address. "Our Better Ordering and Preservation," the title, is a phrase from the Mayflower compact.

"There is nothing that we can say or do about conservation," President Bowman said in part, "that is not embraced in the scheme of nation building. . . . Unless we look at natural resources from the standpoint of 'our better ordering and preservation' it does no good at all to study the

mineral deposits of Illinois, or to look into the conservation of its oil and gas resources, or to lower the rate of soil erosion, or reduce the damage of insect pests and of crop and fruit diseases."

The American Association of Economic Entomologists was officially represented by J. J. Davis,



New Natural Resources Building at Urbana, Ill.

Past President, of Lafayette, Indiana; and P. N. Annand, member of the Executive Committee, of Washington, D. C.; the Entomological Society of America by C. E. Mickel, Secretary-Treasurer, of St. Paul, Minnesota; the Entomological Society of Washington by C. F. W. Muesebeck, President, of Washington, D. C.; the Entomological Society of Ontario by Arthur Gibson, Dominion Entomologist, of Ottawa, Canada.

Among the other entomologists who attended are J. D. Detwiler, University of Western Ontario, Canada; S. A. Graham, University of Michigan; Alvah Peterson, Ohio State University; C. L. Fluke, University of Wisconsin; Curtis W. Sabrosky, Michigan State College; George Steyskal, Detroit, Michigan; W. M. Boesel, Miami University, Oxford, Ohio; and W. E. Ricker, Indiana University. Several of these entomologists attended as official representatives of the institutions with which they are associated.

A large Georgian structure of steel, concrete, and brick, the Natural Resources Building is so planned that all five of its floors may be used for laboratory or office space. With its equipment it represents an outlay of nearly $800,000, appropriated by state and federal governments. It is shared by the Natural History Survey and the Geological Survey.

The Section of Economic Entomology of the Natural History Survey occupies offices and laboratories on the first floor and in the basement. Entomologists in this section also make extensive use of a six-section experimental greenhouse recently constructed south of the new building.

On the second floor are located offices of the Section of Insect Survey. Here also is a large collection room with 2,640 trays in 180 cases and additional cases with adjustable shelves for vial collections.

New equipment for use of the entomologists includes a constant temperature room and temperature control units, laboratory desks and sinks especially designed, chemical hoods, and a compounding room for preparation of insecticides used in experimental work. An extensive library, a photographic dark room, a drafting room, and a machine shop also are available to entomologists.

At the west end of the building on the first floor are the Natural History Survey's administrative offices. Adjoining the combination office and conference room of Dr. T. H. Frison, Chief, and former Editor of the JOURNAL OF ECONOMIC ENTOMOLOGY is a small but well-equipped office and laboratory in which Dr. Frison carries on his insect studies.

The old State Entomologist's Laboratory, formerly headquarters of W. P. Flint and other members of the Section of Economic Entomology, has been retained by the Natural History Survey principally for the game management staff. However, studies of termites and household insect pests will be continued in certain rooms of this building.

ENTOMOPHAGOUS INSECTS

Entomologists who are not on the mailing list of the publishers, The McGraw Hill Co., of New York, will be interested to know that the new book by Dr. Curtis P. Clausen, of the Bureau of Entomology and Plant Quarantine, entitled *Entomophagous Insects*, has just been published.

The book sells for seven dollars but appears to be well worth the price to the working entomologist. A review of the work will be printed in the February number of the JOURNAL.

NOTICE TO SUBSCRIBERS

Engravings of illustrations which appear in Volume 33 of the Journal of Economic Entomology may be purchased by the respective authors or their representatives at one-half cost price. Engravings in the current issue are available under the same terms. This publication reserves the right to destroy those not ordered by March 1, 1941.

Orders to ship engravings to authors should be sent to the Editor at Morgantown, W.Va. from whom cost prices may be obtained. Authors will be billed by the Business Manager of the Association.

This regulation does not apply to engravings used with articles for which the cost of publication has been paid by authors or their representatives. Such engravings will be shipped collect to authors at their discretion if ordered within 30 days from date of publication; otherwise they may be destroyed.

INDEX

Aeolus mellilus, life history of, 816
Aenasius paulistus, 201
Aerial dusting, 912
  spraying, 676
Agromyza angelicae, 199
Agromyzid fly infesting sweetpotato seed, 704
Alabama argillacea, 830
Alfalfa snout beetle
  baits for control of, 639
  control of, 769
  fumigation of soil, 460
Alfalfa weevil, 892
  one new Arizona, 119
Amazon fly, 738
Ambrosia beetle transmits Dutch elm disease, 819
Anabasine, use against apple aphids, 800
Anacampsis fragariella, 121
Anasa tristis, 475
  parasitic castration of, 269
Anthonomus grandis, 682
Anticarsia gemmatilis, 635
Ants, fire, damage, 700
Anuraphis roseus, 336
Aonidiella aurantii, 895
Aphelinus mali, natural dispersion of, 811
Aphid injury and vetch varieties, 833
Aphids
  and narcissus mosaic, 942
  South Sea Island, 200
Aphis
  maidis, susceptibility of corn hybrids to, 623
  rumicis, toxicity of active nicotines to, 734
Apple
  aphids
    technique in experiments, 443
    tests of insecticides against, 800
  delayed dormant spray, 440
  maggots, methyl bromide against, 817
  mealy bug on, 445
  spray deposits, 505
Apple trees, spraying with semi-refined oils, 332
Arsenical grasshopper poisons, effect upon pheasants, 501
Arsenate sprays with soybean flour for codling moth, 862
Artichoke plume moth, 66
Asiatic beetle grubs, control with methyl bromide, 486
Aspidiotus perniciosus, 890
Attractants, for codling moth, 933
  larvae, 342

Bacillus larvae
  nitrite nitrogen test for, 405
  thermal resistance of, 399
Bait, poison, for strawberry crown borer, 812
Baits
  bacteria in, attracting codling moths, 933
  for firebrats, 857
  Japanese beetle, 327
  new, for alfalfa snout beetle, 639
  poison, for grasshopper control, 745
Barium compounds against firebrats, 857
Bathyplectes curculionis, 892
Bean weevils, destroyed by *Pediculoides ventricosus*, 581
Bee
  foods, vitamin content, 396
  losses in Utah, 418
  stings, reaction to, 418
Bees, package, 77
Beet
  leafhopper on tomatoes repelled by pyrethrin dusts, 389
  webworm, Hawaiian, control of, 272
Benzene against tobacco flea beetle, 834
Big-eyed bug bites man, 420
Biological control of
  codling and oriental fruit moths, 431
  mealybugs, 754
Black
  blister beetle, effect of pyrethrum upon, 807
  carpet beetle, effect of paradichlorobenzene upon, 816
  peach aphis, control, 204
  scale,
    frequency distribution of, 113
    hydrocyanic acid against eggs, 107
    winter mortality, 534
  widow spiders, ingestion with canned food, 550
Blattella germanica, 610
Blissus leucopterus, 688
Blow-fly
  larvae, method of destroying in soil, 662
  populations, 166
Blueberry bud mite, 699
Boll weevil
  control, 682, 787
  insecticides, effect on aphids and mirids, 792
Brachyrhinus ligustici, 460, 639
  control of, 769
Bruchidae in cowpea seed pods, 844
Bruchus pisorum, 881
Bud mite, new, on blueberry, 699
Budmoth, field tests for, 336
Bumblebees, insects in nests of, 81

Cabbage
  caterpillars, control, 463
  insects, control by derris-nicotine dusts, 416
Calcium
  arsenate, preparation of, 159
  arsenates, for boll weevil control, 682
  cyanamid, against pear thrips, 950
  cyanide, in control of squash bug, 575
Carnations, infested by onion thrips, 926
Carpet beetles, traps for control of, 651
Carpocapsa pomonella, 143, 340
Catalpa, mealy bug on, 445
Chalepus dorsalis, a pest of soybean, 742
Cherry fruit fly, control, 447
Chicken lice, effect of phenothiazine on, 700
Chinch bug, effect of fertilizers, 688
Chinch bug, hairy, control of, 153
Chloropicrin, fumigation of grain with, 536
Chloropids in houses, 946
Cirphis unipuncta, in Mississippi, 768
Citrus
  potato leafhopper on, 83
  rust mite, cost of control, 393
  tree spraying, rating thoroughness, 85
Clothes moth larvae, openings for, 582
Clothes moths, traps for control of, 651
Coal tar insecticides, new, 596
Coccinellid, introduced into California, 202
Cochliomyia americana, 622, 847, 850
Cockroaches, toxicity of phosphorus to, 193
Codling moth,
  activity of adults, 162
  and organic insecticides, 909

attracted by bacteria in baits, 933
biological control of, 431
control by arsenates and soybean flour, 862
effect of road dust upon, 803
flight habits, 436
larval attractants, 342
new habits of, 200
non-residue sprays for, 340
on stone fruits, 944
pyrethrum against, 143
sprays, 713
spur-burrowing habit of larvae, 796
Color, and effectiveness of Japanese beetle traps, 320
Comstock's mealybug on apple and catalpa, 445
Contributions, scientific at port of New York, 374
Corn borer, mechanical husker in control of, 643
Corn ear worm
control, by dichloroethyl ether, 584
metabolism in, 282
hibernates in Washington, 951
Corn hybrids, susceptibility to *Aphis maidis*, 623
Cotton
flea hopper, host plants, 456
insects, tests of insecticides for, 684
leafworm, 830
Cowpea seed pod insects
Crambus spp., 886
Cresylic acid, replaced with tar oil, 440
Cryolite insecticides, 699
Cubé dusts for pea weevil, 881
Curculionidæ in cowpea seed pods, 844
Cutworm, method for production of, 462
Cyclocephala immaculata, as a test insect, 704
Cylas formicarius, 921

Dendroctonus frontalis, 554
Deposits, mineral oil, on plant surfaces, 155
Derris
dust mixtures, peanut oil in, 736
dusts for pea weevil, 881
effect on black blister beetle, 807
-nicotine dusts for cabbage insects, 416
smoke, toxicity to housefly, 329
Dichloroethyl ether
for gladiolus thrips, 417
for pear thrips, 703
for wireworm control, 280
in mineral oil, against corn earworm, 584
Dinitro-o-cyclohexylphenol, in dormant sprays, 385
Dipping vat, for sheep parasites, 547
Disease, milky, of Japanese beetle, 303
DN dusts, for control of red spider on hops, 614
Dormant spray, for apples, 440
Dust, road, effect on codling moth, 803
Dusting
tent, 942
turf, new machine for, 153
Dusts, insecticidal, application of, 912
Dutch elm disease
and European elm bark beetle, 556
transmitted by *Scolytus sulcatus*, 250

Earwig, European, in Utah, 204
Elm leaf beetle,
control, 264
parasite, biology of, 947
Empoasca fabae, 83
Entomological
considerations, in use of insect killed pine, 773
observations, in California, 141
progress, fifty years of, 8, 15, 21, 30, 58
relations, Federal-State, 779, 784
Entomology,
development of research in, 749
Epicauta pennsylvanica, effect of pyrethrum and derris upon, 807
Epitrix parvula, 467, 834
Equipment, new, for heating honey, 410
Eriophyes vaccinii, 699
Erynnia nitida, 947
Ethylene dichloride, on peach, 199
Eufallia unicostata, new to Puerto Rico, 810
Eugenol and geraniol, attractiveness for Japanese beetle, 818
Euphasiopteryx australis, 202
European
earwig, in Utah, 204
elm bark beetle and Dutch elm disease, 556
European
pine shoot moth, 941
red mite, control of, 385

Federal-State relations, 779, 784
Filbert worm, 852
Fire
ants, damage, 700
-brat baits, 857
-weed nectar and humidity, 870
Fleas, economic importance, 701
Food habits of sparrow hawks, 583
Forficula auricularia, 204
Fumigants, naphthalene and nicotine, 368
Fumigation
of grain with chloropicrin, 536
soil, for alfalfa snout beetle, 460
tests in open tobacco warehouses, 812
with methyl bromide, 176, 921
Fungous disease, epidemics of, 201

Galerucella xanthomelaena, 264, 947
Gasterophilus nasalis, habits of larvae, 382
Geocoris decoratus, bite of, 420
Geraniol and eugenol, for Japanese beetle, 818
Geraniol, properties of, 327
Gladiolus thrips, control, 417, 490
Grape plume moth, 372
Grapholitha molesta, 189, 346
Graphs, for time-dosage mortality data, 139
Grasshopper
control by poison baits, 745
populations, effect of idle land upon, 646
Grasshoppers, a factor in soil erosion, 498
Green bug
injury, survey by airplane, 762
1939 outbreak in Oklahoma, 628
Golden codling moth, 582
Gulf coast tick, biology of, 179
Gypsy moth control, value to uninfested states, 558

Hairy chinch bug control, 153
Hawaiian beet webworm, control of, 272
Heliothis
armigera
hibernation in Washington, 951
metabolism in, 282
obsoleta, 129
Hessian fly, inheritance of resistance, 580
Hive temperature, effect of color of hive covers on, 646
Hollycock, a new pest of, 199
Holly leaf miner, 948
Honey, new equipment for heating, 410
Honeybee
combs,

infested by Mediterranean flour moth, 949
pests of, 81
pollen, trapping, 866
toxicity of tartar emetic to, 872
Hop
insects, field experiments, 112
pests, in Oregon, 70
Hops, control of red spider on, 614
Housefly, control by derris and pyrethrum, 329
Hydrocyanic acid
against red scale, 895
toxicity to eggs of black scale, 107
Hymenia fascialis, 272
Hypera brunneipennis, 119
postica, 892

Illinoia pisi, 833
Insect
activity at light traps, 654
aliens, undesirable, 1
control, effect of wheat harvesting machinery on, 646
damage, evaluation of, 499
food of trout, 544
-killed Ponderosa pine, 773
metabolism and temperature, 361
problems and changes in agriculture, 493
vectors and plant viruses, 827
Insecticidal
dusts, application of, 912
effects of organic compounds, 875
properties of *Phellodendron* spp., 941
residues in cured tobacco, 819
Insecticide
deposits, effect of weather, etc., on, 505
tests against pecan nut casebearer, 379
Insecticides
cryolite, 699
effect of upon aphids and mirids, 792
for boll weevil control, 787
for tobacco flea beetle, 834
household, effect on German cockroach, 610
Insecticides
new coal tar, 596
new, for shade trees, 247
organic, for codling moth, 909
rotenone bearing, 264
Insects
affecting combs of honeybee, 81, 949
cotton, 684
dried fruit, 115
entomophagous, 814
hop, 70
intercepted at New York, 374
list of common names, 708
living, for classroom, 123
of cowpea seed pods, 844
sucking, injuring rose, 658

Japanese beetle
attractiveness of geraniol and eugenol, 818
control by methyl bromide fumigation, 296
milky disease of, 303, 306
traps, 309, 317

Lead arsenate
commercial, particle size of, 170
residues from, 918
substitutes, 447
Leafhoppers, reaction to lawn sprinkling, 584
Leafmining sawfly on violet, 951
Leaf roller, control on roses, 364
Lepidoptera in cowpea seed pods, 844
Lepinotus patruelis, 946
Leptothrips mali, 539
Lice, chicken, phenothiazine on, 700
Light traps for
leafhoppers, 701
mosquitoes, 578
Lime sulfur, effect on
San Jose scale females, 890
treehopper eggs, 583
Locust leaf miner injuring soybeans, 742
Lygaeus kalmii, toxicity of nitrogenous bases to eggs of, 724

Macrosiphum pisi, 620, 736
Male scale, on olives, 203
Mealybug, biological control of, 754
Mediterranean flour moth, in honeybee combs, 949
Melissopus latiferreanus as pest of filberts, 852
Melonworm, control by rotenone dusts, 840
Metagonistylum minense, a parasite of sugarcane borer, 738
Methyl bromide
against
apple maggots, 817
artichoke plume moth, 66
Asiatic beetle, 486
pod borer larvae, 176
sweetpotato weevil, 921
fumigation for Japanese beetle, 296
in aqueous solution, 531
Mexican bean beetle, paris green as repellent, 525
Midges, aquatic, control and biology of, 252
Mineral oil deposits, determination on plants, 155
Milky disease of Japanese beetle larvae, 303
Milky diseases and Japanese beetle larvae, 306
Mosquito
collections,
by light traps, 578, 944
larvae
rearing of, 172
resistance to rotenone, etc., 172
repellents, studies of, 563, 567

Naphthalene fumigants, toxicity of, 368
Narcissus mosaic and aphids, 942
Nectar
in firewood, 870
secretion in poinsettia blossoms, 409
Nicotine
fumigants, toxicity of, 368
peat, sprays for use with, 717
persistence of, on rose bushes, 722
resistance of mosquito larvae to, 172
sulfate, combinations for rose bushes, 722
toxicity of internal doses, 511
use against apple aphids, 800
Nicotines
toxicity of, 734
Nitrogenous bases, toxicity of to eggs of *Lygaeus kalmii*, 724

Oeciacus vicarius, attacking man, 949
Oil
deposit, determination of by color, 905
spray residue, determination of, 900
sprays, effect on treehopper eggs, 583
toxicants and solids added to, 92
Oils, semi-refined for summer spraying, 332
Olives, maple scale on, 203
Oncideres twig girdlers, 561

Onion thrips
control, 278
sprays against, 926
Organic
compounds
insecticidal effects of, 875
toxicity of, to screwworms, 669
insecticides, status of for codling moth, 909
Oriental fruit moth
biological control of, 431
in Japan, 189
larvae parasitization of, 349, 353
Oxyptilus periscelidactylus, 372

Pantomorus
leucoloma, control by methyl bromide, 531
peregrinus, control by methyl bromide, 531
Paradichlorobenzene
against tobacco flea beetle,
effect on black carpet beetle, 816
on peach, 199
Paris green, particle size, 525
Parasite of
Pseudococcus maritimus, 201
Puerto Rican changa, 202
Parasitic castration of *Anasa tristis*, 269
Parasites
external of sheep, 547
of oriental fruit moth, 346, 349, 353
Pea
aphid, 736
as influenced by alfalfa plantings, 137
control, 72
in Maryland, 477
in Virginia, 620
rate of reproduction, 482
weevil control, 881
Peach
control of plum curculio, 451, 453
trees, mounding of, 199
Peanut oil in derris dust mixtures, 736
Pear thrips
control by dichloroethyl ether, 703
controlled by calcium cyanamide, 950
Peat, nicotine, sprays for use with, 717
Peacan nut casebearer, tests of insecticides, 379
Pediculoides ventricosus, destroying bean weevils, 581
Pentatomids, control on tomatoes, 275
Pest control, uniformity in, 776
Petroleum oil distillates, properties of, 591
Phellodendron spp., insecticidal properties of, 941
Phenothiazine,
effect on chicken lice, 700
toxicity to screwworms, 666
Phosphorus, against cockroaches, 193
Phyllophaga
crinita, life history of, 572
lanceolata, life history of, 572
Phytomyza ilicis, 948
Phytotoxic properties, of petroleum oil distillates, 591
Pickleworm, control by rotenone dusts, 840
Pine Shoot Moth, European, in British Columbia, 941
Platynota flavedana, 364
Platyptila carduidactyla, 66
Plot arrangement for timing applications, 357
Plum curculio
control, 451
in Georgia, 453
survival, 950
Pod borer larvae, methyl bromide against, 176
Poinsettia blossoms, nectar secretion in, 409
Poisons, stomach, effect of temperature on, 760
Pollen
substitutes, value of, 397
value of, 397
yields, 866
Popillia japonica, 296
Potato leafhopper
control on citrus, 83
Pseudococcus
comstocki, 445
longispinus, 754
maritimus, parasite of, 201
Psocids infesting
seed, 946
Pyrethrin dusts, repellency of, 389
Pyrethrum
effect on black blister beetle, 807
for control of codling moth, 143
smoke, toxicity to housefly, 329

Quarantine, and insect vectors, 827

Red scale
control, 92
by hydrocyanic acid, 895
Red spider
on hops, control of, 614
tartar emetic for, 579
Repellents, mosquito, value of, 563, 567
Residue
lead and arsenic ratio in, 918
oil spray, determination of, 900
Rhagoletis cingulata, 447
Rose
injury to by sucking insects, 658
leaf roller, control, 364
Rosy aphid, field tests for, 336
Rotenoid, definition of, 416
Rotenone
against apple aphids, 800
-bearing insecticides and the elm leaf beetle, 264
dusts for pickle and melon worms, 840
resistance of mosquito larvae to, 172

Saissetia oleae, 107
winter mortality, 534
San Jose scale, effect of lime-sulfur on females, 890
male, on olive, 203
Sawfly, leafmining, on violet, 951
Scolytus
multistriatus, mating habits, 818
sulcatus, 250
and Dutch elm disease, 250
Screwworm
larvae, nutrition of, 850
migration and pupation, 847
Screwworms, toxicity of
organic compounds to, 669
phenothiazine to, 666
Seed
-infesting psocid, 946
sweetpotato infested by Agromyzid fly, 704
Selenium
as toxicant for insects, 517
for plant injections, 517
Shade trees, insecticides for, 247
Sheep parasites, use of portable vat, 547
Simuliids, feeding activity of, 915
Sod webworms, biology and control, 886
Southern pine beetle, control of, 554
Soybean flour in codling moth control, 862

Soybeans, injured by locust leaf miner, 742
Sparrow hawks, food habits of, 583
Spilonota occellana, 336
Spraying
  aerial, with concentrated mixtures, 676
  citrus trees, 85
Spray
  materials, for use with nicotine peat, 717
  oil, toxicants and solids added to, 92
  residues, 447, 918
    oil, 900
Sprays
  codling moth, 713
  factors in deposit of, 102
  non-residue for codling moth, 340
  orchard, tar oil, 600
  residual poison, 926
Spreaders, new, for insecticides, 247
Squash bug, control by calcium cyanide, 475
Strawberries, control of white grubs in, 693
Strawberry
  crown borer, poison bait for, 812
  leaf roller, western, control, 121
Sugarcane borer, parasite of, 738
Swallow bug, 949
Sweetpotato
  seed infested by Agromyzid fly, 704
  weevil, control of by methyl bromide, 921

Taeniothrips inconsequens, 950
  simplex, 930
Tar oil
  in delayed dormant sprays, 440
  low temperature, in orchard sprays, 600
Tartar emetic
  against
    onion thrips, 926
    red spider, 579
  toxicity to honeybee, 872
Temperature, effect of on toxicity of stomach poisons, 760
Temperatures
  and insect metabolism, 361
  device for maintaining subzero, 419
Tetranychus telarius, 614
Thermobia domestica, 857
Thrips
  distribution of injurious forms, 133
  on gladiolus, field control, 490
Thrips tabaci, 278, 926
Tick, Gulf Coast, biology of, 179
Tobacco
  flea beetle, 834
    breeding hosts of, 473
    host plants, 467
    insecticides for, 834
    migration of, 470
  moth larvae, control of, 819
  warehouses, fumigation tests in, 812
Tomato fruit worm, control, 129
Tomatoes, control of pentatomids, 275
Toxicity of nicotine and naphthalene, 368
Toxoptera graminum, 628
Traps
  color of, in relation to Japanese beetle, 320
  Japanese beetle, 309
  light
    for leafhoppers, 701
    insect activity at, 654
  value of against Japanese beetle, 317
Treehopper eggs, effect of lime sulfur, and oil, on, 583
Trichopoda pennipes, parasite of *Anasa tristis*, 269
Trout, insect food of, 544
Twig girdlers, 561

Velvetbean caterpillar, control, 635
Veratrum viride extracts, insecticidal action of, 728
Vetch, aphid injury in, 833
Violet, attacked by sawfly, 951
Viruses, plant, and insect vectors, 827
Vitamin content of bee foods, 396

White-fringed beetle, activities of adults, 203
White grubs, control by arsenicals in strawberries, 693
White-marked spider beetle, new common name proposed for, 419
White-wash, to control potato leafhopper, 83
Wireworm, control by
  dichloroethyl ether, 280
  substitute crops, etc., 644

Xylosandrus germanus, 819

Formerly

JOURNAL *of* ECONOMIC ENTOMOLOGY

JAN 16 1941

Published by

American Association of Economic Entomologists

at Menasha, Wisconsin

DECEMBER · 1940

Volume 33 Number 6

JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

L. M. PEAIRS, *Editor*, Morgantown, W.Va.

E. P. FELT, *Honorary Editor*, Stamford, Conn.

H. B. WEISS, *Associate Editor*, Trenton, N.J.

ERNEST N. CORY, *Business Manager*, 450 Ahnaip St., Menasha, Wis., and College Park, Md.

PUBLICATIONS COMMITTEE

W. B. HERMS, Berkeley, Calif., *Chairman*. Term expires 1940

S. A. ROHWER, Washington, D.C. Term expires 1940

F. L. CAMPBELL, Columbus, Ohio. Term expires 1941

F. L. THOMAS, College Station, Tex. Term expires 1941

E. J. NEWCOMER, Yakima, Wash. Term expires 1942

A. G. RUGGLES, St. Paul, Minn. Term Expires 1942

J. S. HOUSER, Wooster, Ohio. Term expires 1943

ROGER B. FRIEND, New Haven, Conn. Term expires 1943

E. F. PHILLIPS, Ithaca, N.Y. Term expires 1943

A. B. BAIRD, Belleville, Ontario, Can. Term expires 1944

C. H. RICHARDSON, Ames, Iowa. Term Expires, 1944

Published by

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

AT MENASHA, WISCONSIN

A bimonthly journal published on the 15th of February, April, June, August, October and December, devoted to the interests of economic entomology and publishing the official notices and proceedings of the American Association of Economic Entomologists.

TERMS OF SUBSCRIPTION. To members of the American Association of Economic Entomologists in continental U.S. and possessions, three dollars ($3.00) annually in advance; foreign members, three dollars fifty cents ($3.50). Non-members in the United States, Cuba, Mexico and Canada, four dollars ($4.00) annually in advance. Non-members elsewhere, four dollars fifty cents ($4.50). Single copies, seventy-five cents anywhere.

BUSINESS COMMUNICATIONS of the Association and SUBSCRIPTIONS AND ADVERTISEMENTS to the JOURNAL should be sent to the business manager, E. N. Cory, 450 Ahnaip Street, Menasha, Wisconsin, or College Park, Maryland.

Entered at the Post Office at Menasha, Wisconsin. Acceptance for mailing at special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 538, P. L. and R., authorized May 1, 1936.

THE ENTOMOLOGICAL SOCIETY OF WASHINGTON

—Publications for sale—

Memoir No. 1 of the Entomological Society of Washington
The North American Bees of the Genus Osmia

by GRACE A. SANDHOUSE

A revisionary study of the genus *Osmia* with keys, descriptions, illustrations and distribution records for known North America species.

—Newly Published—

167 large pages; substantially bound in cloth.
Price $3.00, postpaid

PROCEEDINGS OF THE ENTOMOLOGICAL SOCIETY OF WASHINGTON

Complete Sets
Volumes 1 to 42, inclusive, 1884-1940
Price, $121.00

Back Volumes
Volumes 1 to 19, per volume, $2.00
Volumes 20 to 42, per volume, 4.00

Single Numbers
Single numbers of all volumes* each $0.50
* Nos. 1-4, Vol. 9 and Nos. 1-4, Vol. 19 (each issued under one cover) are available only in the complete volumes.
(Price per volume, $2.00)

Separates from the Proceedings

A classified list of available separates of articles which have appeared in the *Proceedings* will be furnished upon request.

DISCOUNT TO MEMBERS

Members of the Entomological Society of Washington and subscribers to the *Proceedings* will be granted a discount of 20 per cent on orders amounting to $10.00 or more.

Domestic shipments prepaid; foreign shipments, f.o.b. Washington.
Make checks, drafts, etc., payable to the Entomological Society of Washington

Address communications to
F. W. POOS, Corresponding Secretary
Bureau of Entomology and Plant Quarantine, Washington, D.C.

McCORMICK FIFTIETH ANNIVERSARY STANDARDIZED INSECTICIDES

RED ARROW GARDEN SPRAY—Highly concentrated Pyrethrum-Rotenone-Soap Spray. Controls many types of insects on flowers, shrubbery, vegetables, fruits.

RED "A" SOAP—is an excellent activator and spreader for use with Red Arrow; reduces cost of spray solution.

ROTENONE GREENHOUSE SPRAY—Controls Spider Mites and many other types of insects, under glass or outdoors. Contains 1½% Rotenone, other Derris Extractives and special wetting agent.

RED ARROW GARDEN DUST—Controls many varieties of insects on vegetables. Contains ¾% rotenone and 30% wettable sulphur.

BLACK ARROW 2700—A special pyrethrum dust for control of mushroom flies.

BLACK ARROW 5000—A compound pyrethrum dust for use in greenhouses on flowers, vegetables, small fruits, etc.

McCORMICK'S ROTENONE DUST—¾% rotenone plus other extractives of rotenone-bearing powder.

TOBACCO PLANTERS' DUST—1% rotenone. Controls flea beetle on tobacco plant beds, newly set plants, growing plants.

PYRETHRUM POWDER—With known high pyrethrin content. So extremely fine it remains suspended in air longer. Contains more killing particles per pound.

DERRIS AND CUBE POWDER—World's finest milled derris and cube powder. Standardized at 4% and 5% rotenone. Will not clog spray nozzles.

SPREADER-STICKER—A new product for insecticides, used in the control of Japanese Beetles and many other insects.

DERRIS EXTRACT—5 grams of rotenone per 100 c.c. plus other toxic derivatives of derris root.

DERRIS EXTRACT (Dry)—25% rotenone and 75% active resins.

ROTENONE CRYSTALS—Solvate, a white crystalline product, 71% rotenone.

For free Spraying and Dusting Charts or other recommendations for the use of any of these products write to:

THE McCORMICK SALES CO., BALTIMORE, MARYLAND

In Canada: McCormick & Co. (Canada) Ltd., 454 King St., West, Toronto, Ontario

*ELGETOL HELIONE

INSECTICIDES AND FUNGICIDES based on WATER SOLUBLE DYESTUFFS

•

PYROLENE M.P. STANTEX SPREADER SOAP TRI-OXYLIN

CARRIERS and STICKERS for Coppers, Sulphurs, Arsenates, Etc.

•

STANTEX DISPERSING OIL

The perfect spreader and developer of Derris Extracts, Nicotine, etc.

•

STANDARD AGRICULTURAL CHEMICALS, INC.

13th & Jefferson Streets Hoboken, New Jersey

* Registered U. S. Pat. Office.

Fumigants

A wide range of effective chemicals with varying degrees of volatility now available

THESE widely used industrial fumigants are suited to protecting products stored in packages or in bulk. Each one combines a low cost per unit treated with maximum effectiveness and minimum hazard.

ETHYLENE OXIDE, a gas, destroys all the life stages of insects, including their eggs. Proper application will prevent the possibility of dormant insects becoming active when a treated product is removed from storage. It also devitalizes mold spores and certain bacteria. However, Ethylene Oxide is flammable.

"CARBOXIDE"* is a gas composed of the fumigant, Ethylene Oxide, plus sufficient non-inflammable carbon dioxide to render the mixture safe under normal conditions. The carbon dioxide also decreases the dosage and time of exposure necessary. "Carboxide" is especially suited for treating foodstuffs since it leaves no obnoxious odors, tastes or residues.

ETHYLENE DICHLORIDE is a volatile liquid which can be used alone or as a non-flammable mixture with carbon tetrachloride. This mixture, called "Chlorasol," is valuable in fumigating furs, furniture, rugs, grains and a variety of other commodities.

Other aliphatic chemicals of interest to the research entomologist are available. Additional data will be gladly supplied on request.

* Trade-Mark.

CARBIDE AND CARBON CHEMICALS CORPORATION
Unit of Union Carbide and Carbon Corporation

UCC

30 East 42nd Street, New York, N.Y.
PRODUCERS OF SYNTHETIC ORGANIC CHEMICALS

ROTENONE - PYRETHRUM

DERRIS ROOT (Derris Elliptica), **CUBÉ ROOT** (Lonchocarpus utilis) and **TIMBO ROOT** (Lonchocarpus urucu): finely powdered standardized to assay 4% or 5% plus the other ether extractives.

Also liquid, soft and powdered extracts of Derris.

ROTENONE CRYSTALS: Chemically pure and 90% technical.

PYRETHRUM FLOWERS: Whole—granulated for extraction—finely powdered for dusting—with definite pyrethrins content.

PYREFUME: Concentrated extract of pyrethrum flowers, in Petroleum Distillate, Pine Oil or Alcohol.

S. B. PENICK AND COMPANY
132 Nassau Street, New York City

Largest Botanical Drug Firm in the World

SULPHURS and INSECTICIDES

"Magnetic-70" Concentrated Sulphur Paste
"Magnetic-Spray" Wettable Sulphur
"Magnetic" Catalytic Sulphur
"Magnetic" Rotenone-Sulphur Dust & Spray
"Magnetic" Humidust
"Magnetic" Pyrethrum-Sulphur Dust
"Magnetic" Cryolite-Sulphur Dust & Spray
"Magnetic" Rotenone Dust
"Crown" Brand Wettable Sulphur
"Electric" Super-Adhesive Dusting Sulphur
"Swan" Brand Superfine Ventilated Dusting Sulphur
"Perfection" Brand Dusting Sulphur
"Owl" Brand Superfine Dusting Sulphur
"Toro" Brand Activated Agricultural Soil Sulphur
"Triangle" Brand Commercial Flour Sulphur
"Magnetic" Cryolite

STAUFFER CHEMICAL CO.
420 Lexington Ave., New York, N.Y.
Chicago, Ill. Freeport, Texas
624 California St., San Francisco, Calif.

Stauffer

Stauffer

DU PONT

INSECTICIDES *and* FUNGICIDES

for Insect and Fungi Control

***LORO:** LORO Contact Insecticide is particularly effective against chrysanthemum midge, mealy bug, red spider, mites and thrips. LORO is also a good aphicide and kills scale insects in the crawling stages. LORO is very economical because of the high dilution used (1:800 to 1:1200).

***GRASSELLI Spreader-Sticker:** GRASSELLI Spreader-Sticker is a highly concentrated spreading, sticking and wetting agent. When properly used with insecticides and fungicides it results in more uniform and complete coverage and better sticking qualities. It mixes readily with water and is highly effective in small quantities.

Copper A-Compound: Copper A-Compound is a comparatively new product which offers better control of fungous diseases and does not require the addition of lime. It has been effectively used on cucumbers, tomatoes, cherries and other specific crops.

Other DU PONT Agricultural Chemicals

*GRASSELLI Lead Arsenate
*NuREXFORM Lead Arsenate
Calcium Arsenate
Dry Lime Sulfur
Lime Sulfur Solution
Flotation Sulfur Paste
*SULFORON Wettable Sulfur
Nicotine Sulfate
Copper Sulfate—Monohydrated
Copper Sulfate—Blue Vitriol
*PARAPONT Paradichlorobenzene
Cryolite—Precipitated
*DUTOX Fluorine Insecticide
Bordeaux Mixture

* Trade Mark

E. I. DU PONT DE NEMOURS & COMPANY

Incorporated

DU PONT

GRASSELLI CHEMICALS DEPARTMENT
WILMINGTON, DELAWARE

SCALECIDE. The safest dormant oil spray in use today. The only miscible oil composed of both vegetable and mineral oils. Used at 1 to 15 for deciduous trees.

D-X. A new form of rotenone and pyrethrum that is compatible with lime sulfur, arsenate of lead, etc. Effective as a contact spray at 1 to 800. Steps up toxicity of arsenate of lead.

SULFOCIDE. A highly concentrated liquid sulfur fungicide, which precipitates true colloidal sulfur when drying. Not compatible with arsenical residue.

SPRAY CATALIZER. A spreader, sticker and safener of sulfur base reducing lead sulphide formation with lime sulfur or Sulfocide and arsenate of lead. Does not deteriorate.

PARA-SCALECIDE. A prepared combination of Scalecide and paradichlorbenzene for use in liquid treatment against peach borers Also used for injection.

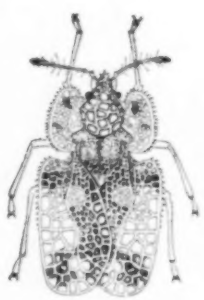
SUMMER SPRA-CREAM. A stabilized 83% summer oil emulsion of low cost, for fruit trees, shade trees, evergreens, etc.

STRAITAR. A stabilized 85% emulsion of tar creosote oil for dormant spraying. Also used with Scalecide or Spra-Cream for delayed dormant spraying. Not unpleasant to use.

SPRA-CREAM. A refined, stabilized 83% lubricating oil emulsion for dormant spraying.

LINSO SOAP. A liquid soap of linseed oil base, without disagreeable odor, for use as a spreader.

B. G. PRATT COMPANY Manufacturing Chemists
50 Church St., New York, N. Y.



Just published

Introducing Insects

By JAMES G. NEEDHAM, *Professor at Cornell University*

This little book is intended for use by those who wish to know something about insects. It tells much about the habits of the commoner kinds of insects, and so explains the methods of dealing with them. It describes and illustrates interesting insects and tells how to rear and preserve them. It contains much about collection making, and gives simple methods that are within the reach of everyone. This outstanding authority has written in language that anyone may understand.

Fully illustrated—$1.50 postage paid

The Jaques Cattell Press, Lancaster, Pa.

JOURNAL OF ECONOMIC ENTOMOLOGY

Prices for back volumes and single numbers of the JOURNAL OF ECONOMIC ENTOMOLOGY are as follows until further notice:

Volume 2, 1909	$3.50	Volume 17, 1924	4.50
Volume 3, 1910	3.50	Volume 18, 1925, except Nos. 1 and 2	3.50
Volume 4, 1911	3.50	Volume 19, 1926, except No. 1	4.25
Volume 5, 1912	3.50	Volume 20, 1927	3.50
Volume 6, 1913	3.50	Volume 21, 1928	3.50
Volume 7, 1914	3.50	Volume 22, 1929	3.50
Volume 8, 1915	4.50	Volume 23, 1930	3.50
Volume 9, 1916	3.50	Volume 24, 1931, except No. 1	3.00
Volume 10, 1917	3.50	Volume 25, 1932	3.50
Volume 11, 1918	4.50	Volume 26, 1933, except Nos. 1 and 2	3.50
Volume 13, 1920	3.50	Volume 27, 1934, Nos. 2, 3 and 6 only, each	1.00
Volume 14, 1921	3.50	Volume 29, 1936, except Nos. 1 and 3	3.00
Volume 15, 1922	4.50	Volume 30, 1937, except Nos. 1 and 3	3.00
Volume 16, 1923	3.50	Volume 31, 1938, except No. 2	3.50
		Volume 32, 1939	4.00

On volumes mailed to foreign countries an extra charge of 50 cents is made to cover postage.

Price of all single numbers except those listed above, 75c each.

Ernest N. Cory, Business Manager, College Park, Md.

INDEX TO THE LITERATURE OF AMERICAN ECONOMIC ENTOMOLOGY

SINGLE VOLUMES

Index I	$5.00
Index II	4.00
Index III	4.00
Index IV	4.00
Index V	4.50

Foreign postage, 50 cents additional for each volume

BARGAIN SALE ON INDICES I TO IV

Complete set, $10.00
Foreign postage, $2.00 additional

COMMON NAMES OF INSECTS, 1937—50¢

No library is complete without these publications and every working entomologist constantly needs them for reference.

Order from

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS
Ernest N. Cory, Secretary, College Park, Md.

CLASSIFIED

Advertisements of commodities for sale or exchange or of services will be entered at 50 cents per issue or $2 per year. Advertisements requesting information for use in publications will be charged at the rate of $1 per advertisement to run as long as space permits. All notices and cash should be sent in advance to Ernest N. Cory, College Park, Md., by the 15th of the month preceding publication.

PHOTOGRAPHS OF ENTOMOLOGISTS. The undersigned desires photos of entomologists to add to the collection now deposited in the Department at Ohio State University. This collection now numbers over 400 portraits, many of them having been included in the "Fragments of Entomological History." It is hoped that a supplement to that volume may include many more and any contributions will be gratefully welcomed. Herbert Osborn, Ohio State University, Columbus, Ohio.

PART THREE of "A Manual of Entomological Equipment and Methods" will be published as soon as sufficient information is compiled and contributed to produce a satisfactory volume. If you have any contributions of subject matter similar to that found in Parts 1 and 2, which you would like to have appear in concise form in this new volume, please send the figures and written matter to Alvah Peterson, Ohio State University, Columbus, Ohio, at your earliest convenience.

All contributions will appear under the contributor's name as in Part 2. Any information or suggestions for improving the Manual will be appreciated.

FOR SALE: The Mosquitoes of North and Central America and the West Indies, by Howard, Dyar and Knab. Carnegie Institution Publication No. 159, 4 volumes. Paper binding and in good condition. Price $100.00.

H. H. Stage, Bureau of Entomology and Plant Quarantine, Washington, D.C.

A SPECIAL SALE PRICE of $3.25 per part either part I or part II of "A Manual of Entomological Equipment and Methods" by Alvah Peterson is announced for a limited period of time *provided* the purchaser sends *cash* (U.S. value) with the order and places the order directly with the author and *not* through a book dealer. Postage is prepaid in the United States; outside the United States add 50 cents per book. The standard sale price for part I is $3.75 and for part II $4.50. To obtain the special price send orders with cash directly to Alvah Peterson, Ohio State University, Columbus, Ohio.

DICTIONARY OF Entomological terms: In preparation. Authors invite correspondence relative thereto and request new words as well as references to articles citing terms or dealing in any way with nomenclature. Parker & Smith, U. S. Entomological Laboratory, Moorestown, New Jersey.

FOR SALE: The Blatchley Insect and Nature Books. Rhynchophora or Weevils of Northeastern America (with C. W. Leng), $4.00; Supplement IV, 1928 (a few copies only), $0.50; Orthoptera of Northeastern America, cloth $6.00, paper, $5.00; Heteroptera or True Bugs of Eastern North America, cloth $10.00, paper, $9.00. Terms, cash with order.

Also, Indiana Weed Books; Fishes of Indiana; Blatchleyana I and II; Gleanings from Nature; Woodland Idyls; A Nature Wooing at Ormond by the Sea; My Nature Book; In Days Agone; South America as I Saw It. Prices on application. Address W. S. Blatchley Club, Earl Brooks, Librarian, Noblesville, Indiana.

Index to Advertisers

American Association of Economic Entomologists, College Park, Md. ix
Carbide and Carbon Corporation, New York, N.Y. v
Cattell Press, The Jaques, Lancaster, Pa. viii
du Pont, E. I. de Nemours & Company vii
Entomological Society of Washington, Washington, D.C. iii
Journal of Economic Entomology, College Park, Md. ix
McCormick Sales Co., The, Baltimore, Md. iv
Penick and Company, S.B., New York City vi
Pratt Co., The B. G., New York City viii
Standard Agricultural Chemicals, Inc., Hoboken, N.J. iv
Stauffer Chemical Co., New York, N.Y. vi

JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ of American Association of Economic Entomologists

MANUSCRIPT RULES and SUGGESTIONS

MANUSCRIPTS for publication should be sent to the Editor, Dr. L. M. Peairs, W.Va. University, Morgantown, W.Va. No manuscript which has been published elsewhere, either wholly or in essential part, will be accepted for publication in the JOURNAL OF ECONOMIC ENTOMOLOGY.

ARTICLES will be published in order of receipt, except for material given priority by committee action or the editor's discretion. Date of receipt will be that date on which copy is accepted in final form for publication, according to the following directions, whether or not it may have been returned to the author for correction. It is therefore to the author's best interest to submit clean copy. Clarity, comprehensiveness and conciseness are most desirable; preferably the paper should be accompanied by the written approval of one or more persons familiar with the subject. The manuscript should be clearly typewritten, double spaced, on one side of the paper only. It should be mailed flat; not folded or rolled. The sheets should not be stapled or pinned. Pages should be numbered correctly. *Author's complete address, to which proof is to be sent, should appear at upper right-hand corner of first page.* Footnotes should be numbered consecutively. Citations should give author, year, title, name of publication, volume, article number, page, and number and kind of illustrations wherever possible, in the order named. Clear, concise headings should be supplied for tables and legends for illustrations. Subheadings intended to be set by themselves in the middle of the page should be avoided. Sideheadings, not more than two per typewritten page, meet most needs. They should be informative, not mere labels or tags. The first letter of each word in a trade name should be capitalized and the word or words underlined.

SIX printed pages are allowed an author free; excess matter will be charged for at the rate of $6.00 per page or part thereof. Prompt publication of acceptable matter may be secured by payment of the entire cost of the paper.

TABLES are expensive. They should always be reduced by authors to the simplest form, *and withdrawn if text or illustrations give the same information.* Tables should be arranged so that, regardless of their length, the number of columns is reduced to the minimum. Papers submitted with more tables than seem necessary, or with tables poorly arranged, will be returned to the author.

ILLUSTRATIONS are accepted at the discretion of the editor. Poor photographs and drawings will delay publication. Where illustrations are a real contribution to the text, two full-page plates or their equivalent are allowed a paper of average length. More than this amount must be paid for by the author. Original, cleanly lettered ink drawings, not photographs, are required for line reproduction. *Numerals and letters that are a permanent part of graphs or other figures must be done neatly. They should be made large enough to allow for reduction and should be spaced liberally.* For graphs, only blue cross-hatched or white drafting paper or tracing cloth should be used. Orange and other color graph papers spoil the appearance of engravings. On the back of EVERY illustration, or engraving where furnished, should be written the name of the author and the paper to which the illustration belongs. Photo-engravings may be obtained through an order placed with the Editor.

SCIENTIFIC NOTES, OBITUARIES and BOOK REVIEWS, written in accordance with the foregoing directions, should be sent to the editor. CURRENT NOTES should be sent to the associate editor, Harry B. Weiss, 616 First Mechanics National Bank, Trenton, New Jersey. HORTICULTURAL INSPECTION NOTES should be sent to R. G. Richmond, Bureau of Entomology and Plant Quarantine, Washington, D.C. *Proof of this material is not sent to authors except by request.*

REPRINTS

Authors will be given opportunity to order reprints at the time they receive galley proof from the printer. Only orders placed at this time (except in the case of Scientific Notes) will be considered official, and authors will be responsible for payment to the Business Manager, E. N. Cory, College Park, Maryland.

The following scale of reprint charges is based on supplying excerpts, that is, separate pamphlets made by cutting apart large sheets and arranging pages in leaflet form, bound by sidewire stitching. This is the cheapest method by which separates can be prepared. The method requires that for an article beginning on a left hand page one extra page must be added to the count to allow for the title on the first right hand page, which would otherwise be blank.

Price Schedule—Mailing Charges Additional

Pages	1	2	3-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32
50 copies	1.60	2.00	2.70	4.25	6.70	7.25	9.40	10.40	12.05	12.80
100 copies	1.95	2.40	3.20	5.10	7.80	8.60	11.00	12.95	15.10	16.20
Additional hundred	.75	.75	1.10	1.60	2.70	3.10	3.70	4.80	5.85	6.20

500 copies, deduct 5 per cent; 1000 copies, deduct 10 per cent.
First 50 covers, $3.00; additional covers at 2 cents each.
Folio reprints (32-page signature *or less*, uncut, folded) *50 only*, $2.50.

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

(Organized 1889; Incorporated December 29, 1913)

OFFICERS

President, HARRY S. SMITH, Riverside, Calif.

First Vice-President, W. A. PRICE, Lexington, Ky.

Secretary, ERNEST N. CORY, College Park, Md.

Vice-Presidents

B. G. THOMPSON, Corvallis, Ore. (Pacific Slope Branch)

O. I. SNAPP, Fort Valley, Ga. (Cotton States Branch)

W. H. WHITE, Washington, D.C. (Eastern Branch)

GEO. S. LANGFORD, College Park, Md. (Section of Plant Quarantine and Inspection)

FRANK R. SHAW, Amherst, Mass. (Section of Apiculture)

C. B. DIBBLE, East Lansing, Mich. (Section of Extension)

C. L. METCALF, Urbana, Ill. (Section of Teaching)

Branch and Section Secretaries

ROY E. CAMPBELL, Alhambra, Calif. (Pacific Slope Branch)

J. T. CREIGHTON, Gainesville, Fla. (Cotton States Branch)

H. B. WEISS, Trenton, N.J. (Eastern Branch)

ROY G. RICHMOND, Washington, D.C. (Section on Plant Quarantine and Inspection)

W. A. PRICE, Lexington, Ky. (Section of Apiculture)

G. E. LEHKER, Lafayette, Ind. (Section of Extension)

ROGER C. SMITH, Manhattan, Kan. (Section of Teaching)

EXECUTIVE COMMITTEE

HARRY S. SMITH, Riverside, Calif.

ERNEST N. CORY, College Park, Md.

CLAY LYLE, State College, Miss.

J. J. DAVIS, Lafayette, Ind.

T. H. FRISON, Urbana, Ill.

E. R. SASSCER, Washington, D.C.

P. N. ANNAND, Washington, D.C.